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Editor: N. A. Marris, M.Sc., B.Com.
Assistant Editor: M. O'Connor, M.Sc.
Department of Scientific and Industrial Research, Wellington

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WHEAT SEED TESTING WITH REFERENCE TO COVERED SMUT DISEASE, PRE-EMERGENCE LOSS, AND FUNGICIDAL DUST COVERAGE

By I. D. BLAIR, Canterbury Agricultural College, Lincoln

Summary

Wheat seed samples were shown to carry *Tilletia* smut fungi to the extent of 17.4 and 8.9 per cent over two seasons.

Proceedures have been described for determining the adequacy of fungicidal dust coverage and it was recorded that of 185 samples from commercial seed distributors, only 11 revealed the 2 oz. per bushel dust load claimed for all. The importance of disinfectant load between 1.5-2.0 oz. per bushel has been emphasized by the results of inoculation experiments featuring the covered smut and pre-emergence diseases of wheat.

Observations have been made on the nature of seed dusting machinery in use throughout the wheat-producing area of New Zealand; those mechanical features with which efficiency is associated have been outlined.

The evidence demonstrates justification for a disinfectant dust cover standard within the requirements of official seed inspection and certification.

INTRODUCTION

THE value of dust disinfection of seed wheat under New Zealand conditions as a preventive of covered or stinking smut disease was demonstrated by Neill's investigations (1925, 1927, 1934). The fungi which Cunningham (1924, 1945) associates with this disease are *Tilletia caries* (DC.) Tul. and *T. foetens* (Berk. and Curt.) Schroet., and it is believed that seed disinfection now generally carried out has resulted in a marked decline in the occurrence of these fungi, at least on wheat seed. Wheat seed disinfection is now generally practised in New Zealand, and Blair (1937) recorded that all of 236 farmers covered by a crop survey were using disinfected wheat, though at that time slightly more than half only were using dry-dusted lines of seed. Since then, the available evidence indicates that all previously applied disinfection methods, including the liquid chemical steeps, have been superseded by dry-dusting, using such organic mercury compounds as Ceresan and Agrosan. Farm treatment of seed seems to be entirely out of favour, and merchants responsible for seed wheat distribution now provide facilities for dry-dusting the seed concurrently with machine dressing. The grower is charged approximately 10d. extra per bushel for dusted seed, which on the basis of a 200,000 acre crop, means that the annual expenditure on wheat seed disinfection is in the vicinity of

£13,000. The dust treatments are used also for barley and to a lesser extent for oat seed; thus an appreciable sum of money is invested by the growers in dust treatment.

Although flour millers and grain merchants have their own evidence that covered smut (bunt or stinking smut) is no longer as serious as it was twenty-five years ago, no recent survey of the position in respect of this disease has been reported. This investigation concerns itself partly with the question—to what extent does covered smut still occur on seed wheat? But in view of the impression among growers that the treatments are sound and efficient, the investigation has also been concerned with evidence relating to standards of efficiency with which the preventive treatments are performed by the commercial dusting machinery at present in use.

OCCURRENCE OF COVERED SMUT FUNGI ON WHEAT SEED

Experimental

Samples of threshed wheat submitted to the Wheat Research Institute laboratory were used in this study and examined for *Tilletia* chlamydospore load using a centrifuge procedure adapted from the method described by Russell and Ledingham (1941) in their examination of the disease factor in Saskatchewan grain samples.

The samples in 40 g. lots (in duplicate) were each mixed with 60 ml. sterile water in flasks, shaken mechanically for five minutes, after which 12 ml. portions of the water suspension were centrifuged at 2,500 r.p.m. for five minutes. All but 0.5 ml. of the suspension was poured from the centrifuge tubes, and this portion containing the solids thrown down was smeared and dried on a slide for microscopic examination.

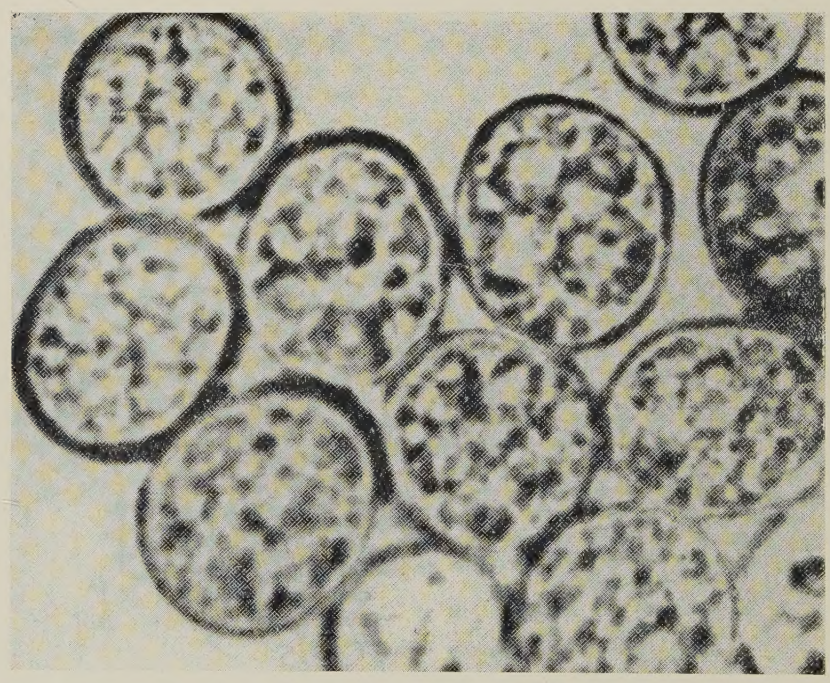

FIG. 1.—Smooth spores of *Tilletia foetens* (from Fischer and Hirschhorn, 1945).

Thirty microscopic fields using oil-immersion magnifications were examined per sample and counts made on the occurrence of *Tilletia* spores. As standards for identification purposes, two lots of 100 sound wheat grains were shaken respectively with a spore-ball of a herbarium sample of *Tilletia caries* and *T. foetens*. These directly infected samples were treated in the centrifuge manner described and the resultant slides were used as checks for comparative purposes. These control or check samples revealed by haemocytometer count approximately 10,000 *Tilletia* spores per wheat grain:

Spore identifications were made using these check slides and also by reference to the following descriptions of the fungi by Fischer and Hirschhorn (1945).

"*Tilletia foetens*—spores globose to ovoid or elongate, light greyish brown to dark oliveaceous-brown; smooth: chiefly 17-20 microns diameter (Fig. 1).

Tilletia caries—spores globose to sub-globose, occasionally ovoid; light smoky brown to reddish brown, with reticulate epispore varying from minute shallow meshes to large deep reticulations: 15-23 microns diameter" (Fig. 2).

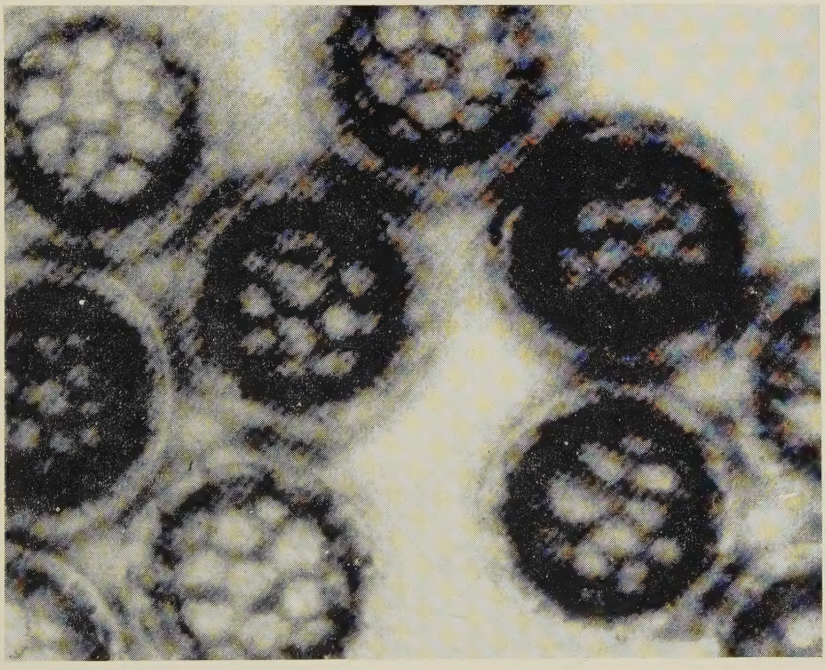

FIG. 2.—Reticulate spores of *Tilletia caries* (from Fischer and Hirschhorn, 1945).

Results

The results of these observations on the occurrence of covered smut spores on harvested wheat are shown in Tables I and II, which relate to two seasons.

TABLE I. THE OCCURRENCE OF *Tilletia* SPORES ON WHEAT SEED FROM 1947 HARVEST
(Total chlamydospores in 30 microscope fields per sample)

Sample Origin.	Number Samples Tested.	No. Samples of each Spore Load Rating.*		
		Nil.	*Tilletia caries.*	*T. foetens.*
Springs-Ellesmere	10	8	—	2 Trace minus
Waipara	10	10	—	—
Amuri	12	12	—	—
Cheviot	6	6	—	—
Kowai	4	4	—	—
Rangiora	7	6	1 Trace minus	—
Eyre	9	7	1 Trace minus	1 Trace minus
Malvern	6	6	—	—
Ashburton	20	16	1 Moderate 1 Trace minus	2 Trace minus
Timaru	9	8	—	1 Trace minus
Waimate	32	25	2 Trace minus 1 Severe	4 Trace minus
Waitaki	41	29	7 Trace minus	5 Trace minus
Otago	14	12	1 Trace minus	1 Trace minus
North Island	8	7	—	1 Trace minus
Totals :	188	156	13 Trace minus 1 Moderate 1 Severe	17 Trace minus

* The following load ratings of Russell and Ledingham (1941) were used :

Trace minus	less than 1 spore	average per	microscope	field
Trace	1 spore	,,	,,	,,
Trace plus	2-3 spores	,,	,,	,,
Slight	4-10 spores	,,	,,	,,
Moderate	10-50 spores	,,	,,	,,
Severe	over 50 spores	,,	,,	,,

TABLE II. THE OCCURRENCE OF *Tilletia* SPORES ON WHEAT SEED FROM 1948 HARVEST

Sample Origin.	Number Samples Tested.	No. Samples of each Spore Load Rating.		
		Nil.	*Tilletia caries.*	*T. foetens.*
Springs-Ellesmere	6	5	1 Trace minus	—
Waipara	3	2	1 Trace minus	—
Amuri	3	2	—	1 Trace minus
Cheviot	2	2	—	—
Kowai	1	1	—	—
Eyre	2	2	—	—
Malvern	13	12	1 Trace minus	—
Ashburton	11	10	1 Trace	—
Timaru	3	3	—	—
Waimate	16	15	1 Trace minus	—
Waitaki	11	10	1 Trace minus	—
Otago	2	2	—	—
Marlborough	6	6	—	—
Totals :	79	72	1 Trace 5 Trace minus	1 Trace minus

The information in these tables supports the belief that covered smut disease in wheat is at present within a measure of good control. Generally the fungi responsible (mostly *T. caries*) occur only as a trace, and over two seasons, in the proportions of 17.4 per cent and 8.9 per cent of the samples examined. It is known that a direct relationship exists between *Tilletia* spore load and the amount of covered smut

disease appearing in the crop sown with infected seed. Thus Heald (1921) concluded that maximum infection arose from spore loads between 3,500 and 150,000 per grain (200 - 1,000 per microscope field) and Lobik (1926) demonstrated that infection should be light where wheat seed carried no more than 500 spores per grain. It is clear therefore, that the infected samples detected in this survey could not generally be classified in a category with which would be expected a severe outbreak of disease. On the other hand it is apparent that small foci of light infection continue to exist. Small or incipient disease infections cannot be viewed as of no consequence, especially with covered smut, where the causal organism possesses an infinite capacity to multiply rapidly if unchecked. Every effort to prevent these foci developing into major outbreaks should be urged upon growers and seed distribution agencies.

It might be claimed that a state of practical covered smut disease control has resulted in New Zealand from the general practice of seed disinfection. While not denying the importance of the part these treatments have played, it is reasonable to suggest that covered smut prevention has also been greatly assisted by the system of pure seed distribution now in use. This system involves the maintenance by the Agronomy Division, Department of Scientific and Industrial Research, of pure seed of varieties, which after hot-water treatment are multiplied by Lincoln College, the resultant seed once removed from hot-water treatment being then distributed by merchants. This system has figured particularly in reducing the significance of the loose smut disease caused by *Ustilago tritici,* which, as distinct from *Tilletia* spp., is carried inside the grain. Such systems of pure seed distribution are important in eliminating seed-borne diseases and there can be little doubt that such forms of seed certification and maintenance of treated, disease-free stock have contributed to the generally satisfactory position relating to covered smut demonstrated in the evidence of Tables I and II. Nevertheless dry dust disinfection must continue to be the standard preventive or precautionary measure against air or soil-transmitted covered smut spores.

EFFICIENCY OF COMMERCIAL SEED WHEAT DISINFECTION

Experimental

Inoculated agar plate technique:

This technique was developed, based upon the procedure described by Mead (1945). In the work at Lincoln, a test fungus *Cladosporium herbarum* was prepared in the form of water suspensions of the fungus spores transferred from pure cultures of the organism. One millilitre portions of the suspension were flooded over the potato-dextrose-agar surface on Petri culture dishes, after which grains from the sample under examination were planted on the agar surface which had been previously inoculated with the spores of the test fungus.

After three days at room temperature (20°C.), it was found that the inoculated fungus had grown profusely over the agar surface except in the vicinity of grains presumably well covered with dust disinfectant.

FIG. 3.—Undusted seed showing development of seed-borne fungi and an absence of any inhibition of the inoculated test fungus.

FIG. 4.—Well-dusted seed showing distinct inhibition of inoculated test fungus.

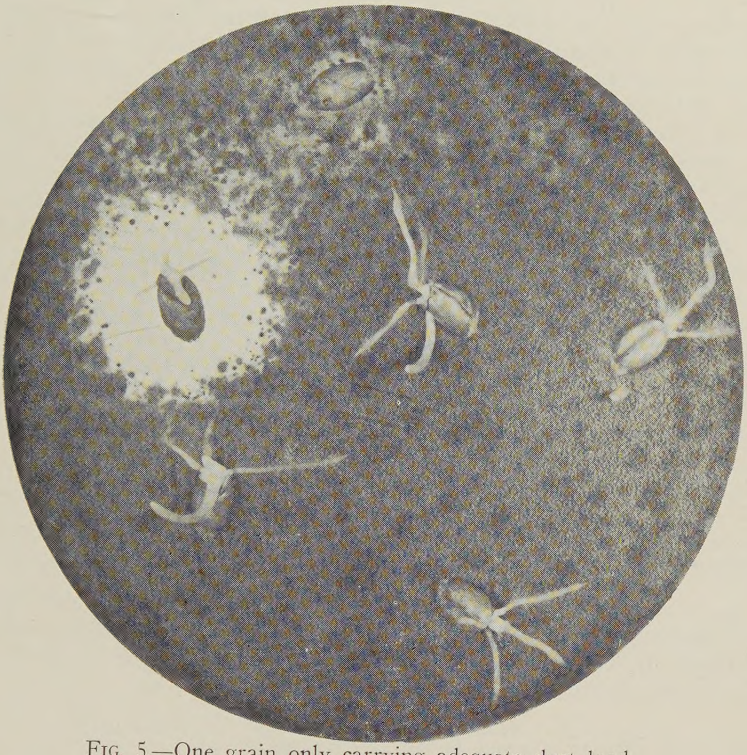

FIG. 5.—One grain only carrying adequate dust load.

FIG. 6.—A range of commercial samples all reputed to carry 2 oz. disinfectant dust per bushel.

A zonation or inhibitory effect was apparent in varying degrees as illustrated in Figs. 3 - 6. Comparing Fig. 3 (grain with no dust disinfectant) with Fig. 4 (well dusted), the zonation effect can be attributed to the effect of the toxic active ingredient in the organic mercury dust, in preventing the growth of *Cladosporium* within the zone where the chemical had spread.

An attempt was made to use the extent of this *Cladosporium* inhibition as a measure of efficiency in dust coverage of wheat seed. The test samples comprised 12 grains in each of two plates prepared as outlined above. Other fungi were used initially, including types like *Fusarium avenaceum* and *F. graminearum* known to be actively pathogenic to wheat compared with the *Cladosporium* organism which in itself produces no disease in germinating wheat seed. The *Fusarium* fungi exhibited exactly the same effect of a limitation in growth in the vicinity of well-dusted grain.

Using this inoculated plate procedure, the status of samples regarding dust load was determined using a numerical rating whereby each grain on the duplicate inoculated test plates was scored as follows:—

0 indicates *nil* inhibition of inoculated fungus.
1 „ *slight* „ „ „
3 „ *distinct* „ „ „

$$\text{Numerical Rating} = \frac{\text{Sum of individual scores} \times 100}{\text{No. grains in sample} \times \text{Maximum score (3)}}$$

Over one season (1946) the inoculated plate procedure was adopted in examining disinfectant dust coverage on 102 wheat seed samples submitted by 37 commercial seed firms throughout the South Island. The results obtained are shown in Table III.

TABLE III. NUMERICAL RATING OF DUST COVERAGE USING *Cladosporium* INOCULATED PLATES

Rating Class.	Number Samples.
Nil	20
Less than 10	17
Less than 20	9
20 - 30	4
30 - 40	9
40 - 50	4
50 - 60	5
60 - 70	4
70 - 80	8
80 - 90	8
90 - 100	14

	DUST LOAD	
Sample No.	Washing Procedure.	Determined from Mercury Content.
1	1·7	1·1
2	3·0	2·3
3	1·5	1·3
4	1·4	1·2
5	1·4	1·1

This qualitative test at least served to demonstrate that with 63 per cent of samples submitted exhibiting less than a 50 per cent standard of dust coverage efficiency, the position deserved fuller examination. That

the variation in coverage was not connected with a varying capacity of seed of different wheat varieties to retain or carry dust was demonstrated by hand dusting seed of well-known varieties at the standard 2 oz. per bushel rate. Small seed lots with the requisite amount of dust were vigorously hand shaken for 2 min. in a tin and then subjected to the fungus plate test. A 100 per cent rating was obtained for all the varieties, so tested, namely, Tuscan, Cross 7, White Fife, Fife, Tuscan, Jumbuck, Yoeman, Hunters, Eureka, Marquis, Holdfast and Dreadnought. It was concluded that wheat seed regardless of variety, will carry the 2 oz. per bushel dust load and reveal a 100 per cent rating of efficiency.

The inoculated plate test, however, was found to be of value only as a guide or indication of dust coverage as between well dusted and very lightly dusted or undusted samples. As shown in Table III, 20 samples gave a *nil* rating as measured by the fungus plate test, whereas a second procedure described below, showed that in fact at least some dust was on the grain, though in a dosage insufficient to limit growth of the test fungus. Nevertheless the above described method has proved useful in demonstrating the extreme variation which may exist in dust coverage of grain samples all reputed to have been treated at the rate of 2 oz. per bushel.

Measurement of Dust Load Technique:

This second procedure provided for a measurement of actual dust load on grain samples. The method as under, features washing the grain samples, collecting sediment and weighing the amount of disinfectant dust eventually separated out.

The procedure* was suggested by Mr. A. F. R. Adams, Chemistry Dept., Lincoln College, who describes the details as follows:—

Weigh a representative sample (50 - 100 g.) grain under test into a 400 ml. beaker. Add approx. 100 ml. hot water and stir vigorously with a rod for a minute or two. Decant the liquid through a perforated funnel (Buchner or Hirsch) into a 500 ml. cylinder or similar tall vessel.

Repeat this process twice (making three washings in all) and finally transfer the grain to the funnel and wash out the last traces of dust from the beaker with the aid of a rubber policeman.

Allow the combined washings to stand until the dust has settled sufficiently to allow most of the supernatant clear water to be decanted and discarded, leaving all the dust in the cylinder. (Fig. 7.)

The dust may now be filtered off on a tared Gooch or similar crucible and washed with hot water; crucible and dust dried at 100°c. and reweighed.

* This same procedure can be used in determining dust load on other dry dust disinfected seeds. The dust load on garden peas, linen flax, oats and barley, has been examined after the manner described, the weight of dust being calculated according to the formula above, with the provision that the particular bushel weight (of peas, linen flax, oats, barley) is substituted for that of wheat. Flax seed requires a modified treatment in order to contend with the swelling of the mucilaginous coating of the seed when in contact with water. The procedure followed by Baylis (1941) is used with flax seed, involving a 5 per cent potash alum steep instead of water, used in washing dust from the seed.

FIG. 7.—Apparatus used in washing disinfectant dust from seed. Left cylinder showing extent to which dust had settled after 10 hours.

Alternatively, wash out the dust into a tared centrifuge tube (50-100 ml.), spin, decant the water, dry and reweigh.

If "a" is the weight of dust from sample weight "A" of wheat grain (both in grams):

$$\text{Then (1) } \frac{a}{A} \times \frac{60 \text{ (bushel weight in lb.)} \times 454 \text{ (grams per lb.)}}{28.4 \text{ (grams per oz.)}}$$

$$\text{or (2) } = \frac{a}{A} \times 960 = \text{ounces disinfectant dust per bushel of wheat.}$$

It is essential not to allow the hot water to remain in contact with the grain for a longer period than is necessary for the above procedures to be carried out, otherwise the grain will swell and burst, and the resulting glutinous suspension will cause inconvenience later.

Some idea of the reproducibility of the method can be gauged from the following figures of eight determinations on two different samples:

(1) Mean 1.10 oz. per bushel
Standard error ± 0.024

(2) Mean 1.15 oz. per bushel
Standard error ± 0.012

This test makes no claim to extreme accuracy, but is considered satisfactory for use as a control test to determine the effectiveness of the dusting procedure as carried out by seed merchants. The figure obtained must be weighted somewhat in favour of dust load, as the value will include the weight of any extraneous matter which might also be carried on the seed coat. The range of this extraneous matter was shown to be 0.05-0.20 oz. per bushel.

Representative commercial samples for which dust load determinations had been made by the washing procedure were also examined by the Dominion Analyst, Wellington, with a view to determining the dust load, based upon an analysis of mercury content. The results of the two tests were as follows:

This evidence confirms the suggestion above that the figure obtained by the washing procedure is likely to err on the generous side regarding the amount of dust on the sample.

Dust Coverage Results

The position among 185 commercial samples derived from 40 firms or agencies and of 1947 and 1948 harvest seed is shown in Table IV and Fig. 8.

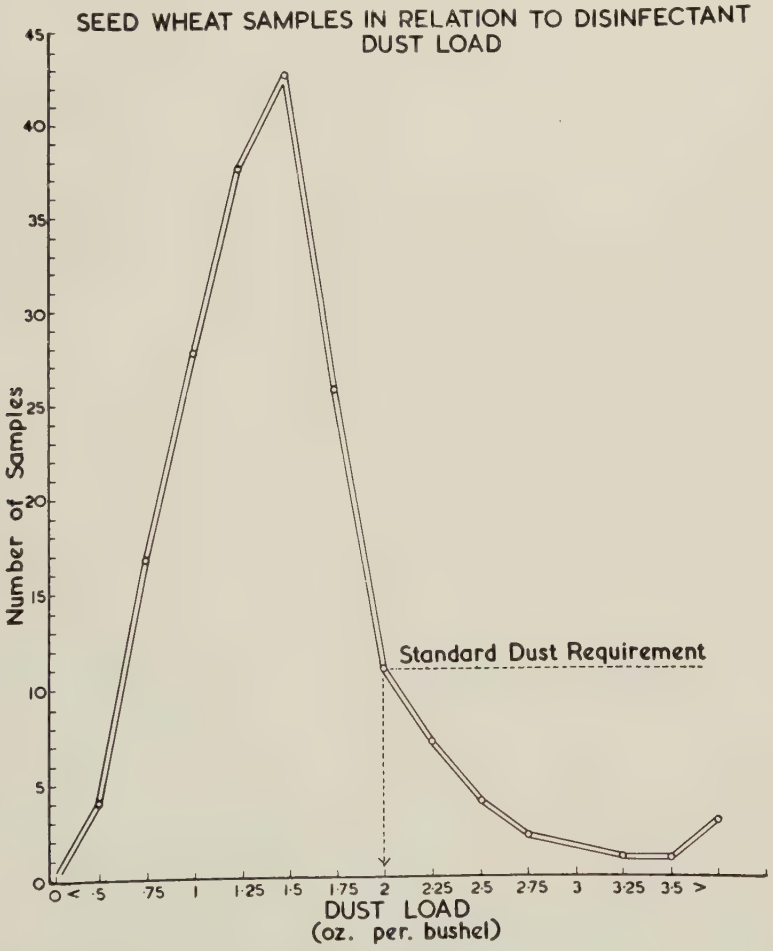

FIG. 8.—Disinfectant dust load on samples stated to carry 2 oz. per bushel.

Table IV. Disinfectant Dust Load on Commercial Seed Wheat determined by Washing Procedure

Class. (oz. dust per bushel)	Number of Samples per Class.	
	1947	1948
Less than 0·5	4	0
,, ,, 1·0	30	15
,, ,, 1·5	41	39
,, ,, 2·0	16	22
,, ,, 2·5	8	3
,, ,, 3·0	1	1
more than 3·0	2	3

Dust Load.	Grading.
Over 10 oz. per bushel	Over-dusted*
1·5-2·0 oz. ,,	Distinct
1·0 oz. ,,	Fair
0·5 oz. ,,	Slight
0·0 oz. ,,	Undusted

* This was a freak sample notwithstanding the fact that it had been obtained from a seed distributing firm. The grain at a glance could be seen to be heavily coated, with in addition, a heavy distribution of free dust between grains.

It is shown (Fig. 8) that of 185 commercial samples tested by the wash procedure, only 11 revealed the 2 oz. per bushel dust load which was claimed for all samples. 79 per cent of samples tested were between the 0.75 - 2.0 oz. per bushel range and 43 per cent between 1.5 - 2.0 which it is suggested should be taken as at least the standard requirement.

The Importance of Amount of Dust Disinfectant

Relation to covered smut prevention and to plant growth

In Table I is recorded one line of wheat severely infected with *T. caries* and originating in the Waimate district. Dust scourings were obtained from the flour-miller who handled this line of wheat and were found to consist predominantly of *Tilletia* spores suitable for seed inoculation purposes. For the experiments, a number of seed lots of 1947 harvest, Cross 7 wheat were selected, the dust load of which had previously been determined as indicated below:—

Portions of these lines were shaken with the *Tilletia* spore inoculum to provide inoculation rates of 1 : 100 and 1 : 200, i.e., 1 part of grain to 100 and 200 parts by weight of inoculum. These rates were in accord with those used in the covered smut inoculations described by Holton and Heald (1941) and Weston (1945). The seed so treated was eventually sown in two trials.

Trial 1.—Sown in field plots; autumn sowing mid-May, 1947, and spring sowing August, 1947; single rows with seed spaced at 3 inches apart and eight replicates of each treatment.

* This was a freak sample notwithstanding the fact that it had been obtained from a seed distributing firm. The grain at a glance could be seen to be heavily coated, with in addition, a heavy distribution of free dust between grains.

Trial 2.—Treatments sown in wooden boxes of rich garden soil; 20 grains per row of each treatment—in duplicate; maintained in glass house with regular watering throughout the winter period May-August, 1947.

The observations made are summarized in Tables V and VI.

TABLE V. PLANT ESTABLISHMENT IN RELATION TO DUST LOAD
(Mean figures of established plants per row - not percentage germination)

Dust Load.	Trial 1. (Autumn sowing)	Trial 1. (Spring sowing)	Trial 2.
Overdusted (> 10 oz.)	22	18	10
Distinct (1·5-2·0 oz.)	34	67	17
Fair (1·0 oz.)	33	63	19
Slight (0·5 oz.)	35	57	18
Undusted	32	64	17

TABLE VI. COVERED SMUT DISEASE IN RELATION TO DUST LOAD*

Dust Load.	Trial 1. (Autumn sowing)	Trial 1. (Spring sowing)	Trial 2.
Undusted	16	4	6·0
Slight (0·5 oz.)	11	2·5	2·0
Fair (1·0 oz.)	2	nil	1·0
Distinct (1·5-2·0 oz.)	nil	nil	nil
Overdusted (> 10 oz.)	nil	nil	nil

* In Trial 1, for both sowings, 30 ripe ears were collected per row or 240 ears per treatment, and each grain in the spikelets was examined. In Trial 2, all mature ears were harvested and examined. The percentages given are of ears showing any degree of covered smut disintegration of grain, confirmed in all cases by microscope examinations.

From the evidence in Table V it was concluded that an excessively heavy disinfectant dust load adversely affected final plant establishment. It was also observed that those plants in the over-dusted treatment which survived were very stunted and delayed in growth. Apparently a phyto-toxic effect of excessive organic-mercury dust limited growth, the effect being depicted in Fig. 9. On the other hand, dust loads between 0.5 - 2.0 oz. per bushel generally had the effect of improving the degree of plant establishment over the result obtained from undusted seed. This result may suggest that any quantity of dust up to 2.0 oz. per bushel is satisfactory in relation to plant establishment in natural soil, and in the interest of economy the minimum quantities of dust might serve the purpose. But from Table VI it is clear that covered smut prevention seems to require a dust load in the vicinity of 2 oz. per bushel. Lighter ratings though contributing to satisfactory plant establishment were not sufficient to prevent significant outbreaks of covered smut. It will be appreciated that a very small ear infection of this disease could still be sufficient to lead to extensive external seed contamination when diseased and healthy ears were threshed in the drum of threshing machinery. In respect to this disease therefore, it seems that a standard rate of 1.5 to 2.0 oz. of disinfectant dust per bushel must remain the objective in this type of seed treatment. Further evidence in support of this contention was obtained in another series of experiments described below.

Relation to germination in the presence of foot-rot fungi

Three species of *Fusarium* known to be associated with pre-emergence loss in germinating wheat were grown as inocula on sterile oat-hull mash in flasks. After flask inoculation, the fungi were allowed to develop until this medium was overgrown and the fungi were sporulating abundantly. Steam sterilized soil adjusted to 50 per cent water saturation was then inoculated by mixing measured amounts of soil with 5 per cent by weight of inoculum. Ten days after this soil inoculation, the Cross 7 seed used in the previously described experiments was sown—12 grains per pot in triplicate series. Pots were weighed with their contents and water losses during the course of the experiment were adjusted by additions of water to restore pot weights. The experiment was conducted at room temperatures and the results of plant emergence are shown in Table VII.

Table VII. Germination of Wheat in the Presence of Heavy Inoculations of *Fusarium* spp., using Seed with a Range of Disinfectant Dust Load (total of triplicate, pots each with 12 grains)

Inoculum.	Dust Load.				
	Overdusted. (> 10 oz.)	Distinct. (1·5-2·0 oz.)	Fair. (1 oz.)	Slight. (0·5 oz.)	Undusted. (no dust)
Fusarium culmorum	35	34	35	28	29
F. avenaceum	35	34	31	30	26
F. graminearum	34	34	33	30	26
Totals	104	102	97	88	81

Although the excessive dust rate appeared to afford the greatest measure of protection against pre-emergence loss, the plants which developed were severely stunted, revealing the phyto-toxic effect referred to earlier and illustrated in Fig. 9. This adverse effect was not apparent where seed dusted at the rate of 1.5 to 2.0 oz. per bushel was sown, and from the figures presented in Table VII it would seem that as dust load decreases from the 1.5 to 2.0 oz. per bushel standard, protection against pre-emergence loss diminishes. This result does not parallel those reported by Blair (1938) relating to field experiments with dust-infected wheat seed sown in field soil heavily inoculated with *Fusarium culmorum*. In these earlier trials it was shown that the dust rates of 0.25, 0.75 and 2 oz. per bushel all equally assisted wheat emergence in the presence of foot-rot fungi, and significantly improved germination compared with that of undusted seed. The divergence in the results of these two sets of experiments should not, however, prejudice the significance of disinfection treatment in affording protection to wheat seed germinating in the presence of pathogenic fungi capable of producing pre-emergence mortality in the absence of dust protection. As an added insurance, the upper level of 1.5 to 2.0 oz. per bushel should be used especially as the experiments covered by Table VI indicate that these quantities appear necessary to prevent covered smut development.

At this juncture, reference should be made to the work of Russell (1946) in Canada, who concluded that it was safe to sow, without fungicidal treatment, seed grain which shows no more than a trace of smut,

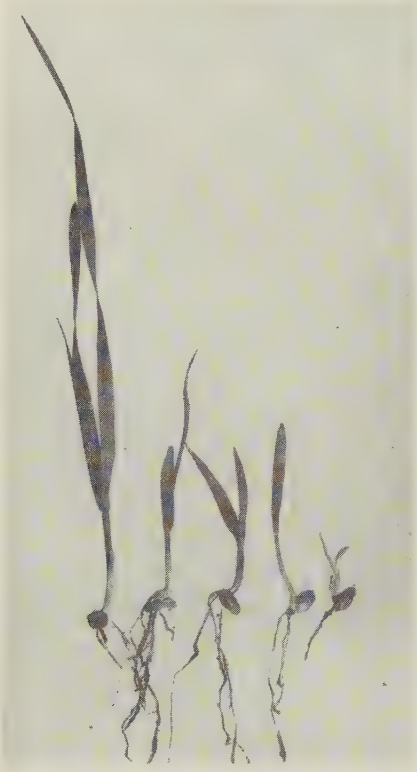

FIG. 9.—Stunted plants as grown from heavily overdusted seed. All plants are the same age, but the one on the left was grown from seed carrying 2 oz. dust per bushel.

provided the grain is free from other important seed-carried diseases. In six years Russell found 80 per cent of tested seed to be free of covered smut infection and as a result of his studies has recommended that dusting be discontinued in the demonstrated absence of *Tilletia* infection. The Canadian work, however, relates to spring sowings. In New Zealand where wheat generally is autumn sown, it is likely to be exposed to some degree of smut and other fungus infection in the soil during the longer growing period. In Canada, Russell (personal communication) states, "Under conditions of spring sowing and a very rapid, short, growing period of three months with no winter dormancy, soil infection by smut is not believed to occur to any appreciable extent." In New Zealand there can be no question from the evidence presented in this paper that universal seed disinfections must continue and at the rate of 1.5 to 2.0 oz. per bushel.

SEED DUSTING MACHINERY

Types used in New Zealand

During the course of this investigation, many seed-cleaning and dusting establishments were visited and from observations made, there appeared to be neither uniformity in design of dusting machine nor

unanimity of opinion as to which type of machine was the most efficient. In general, the dusting machines in use conformed to one of three types, the essential features of which are summarized below.

Rack-feed, revolving cylinder type (Fig. 10):

The dust is fed into a stream of wheat by a rack-feed consisting of a number of measures which slowly move across an opening. The amount of dust flow is determined by the speed with which the rack flow is moved. Dust and seed are given a preliminary mixing by a slowly-rotating spiral in a casing. Final mixing is achieved by passing seed and dust through a revolving cylinder which has cellular indentations on the inner surface. Within this cylinder the mechanical action involves lifting the seed up a certain distance and then allowing it to fall. The cylinder revolves at an angle to the horizontal, thus the materials move along the cylinder length. The general action of this machine is gentle as the seeds are merely rolled over each other.

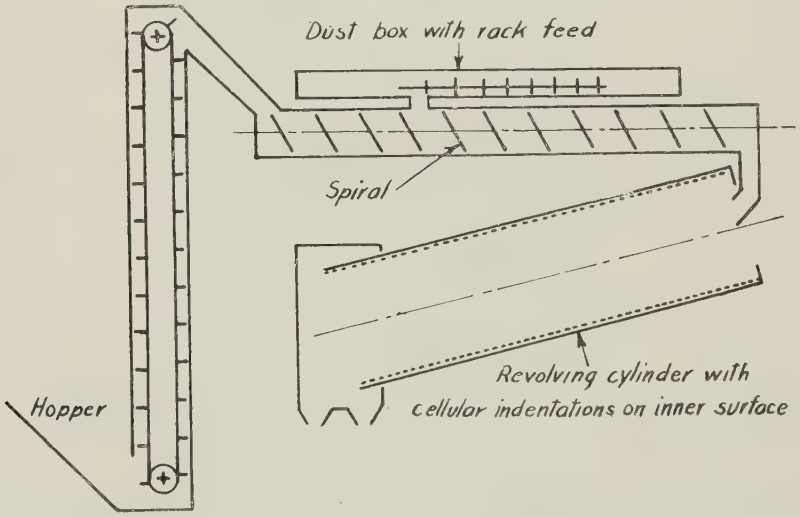

FIG. 10.—Machine with rack-feed and revolving cylinder mechanism.

Star-feed, revolving cylinder type (Fig. 11):

The cylinder mixing action is identical with that described in the first type. Dust is fed with a conventional star-feed mechanism and excess dust is removed through a gauze strip at the end of the cylinder. An exhausting fan is fitted to the bagging chute which draws dust-laden air from the chute and ejects this outside the building. This fitting has been introduced presumably to prevent dust from being inhaled by operators. This draught system has not been shown on the diagram.

Spiral feed type (Fig. 12):

The dust feed in this instance is a long, narrow box within which is a slowly-revolving spiral or worm, the speed of which determines rate of dust feed. Mixing is achieved by a spiral revolving inside a stationary cylindrical casing. A portion of the bottom of the bagging chute is fitted with a piece of gauze allowing excess dust to fall through. This machine possesses no cylinder and mixing of dust and seed is effected by a moderate stirring action within the spiral casing.

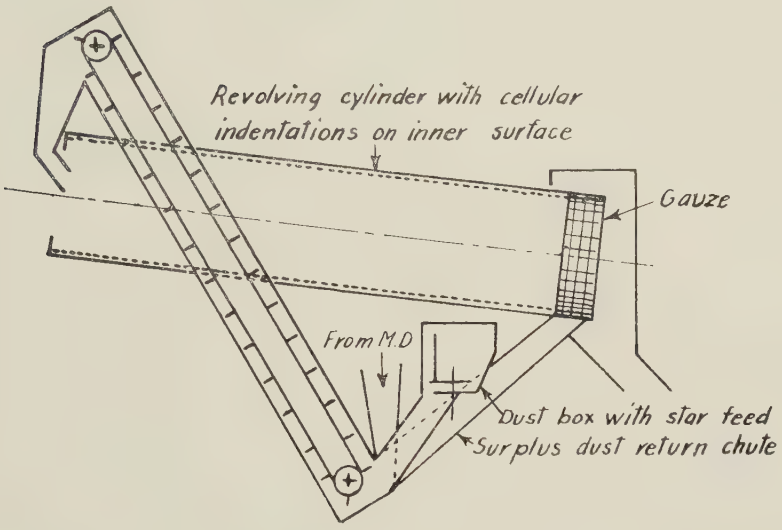
Revolving cylinder with cellular indentations on inner surface
Gauze
From M.D
Dust box with star feed
Surplus dust return chute

FIG. 11.—Machine with star-feed and revolving cylinder mechanism.

Some detailed observations were made on a Fig. 11 type of machine operated at Lincoln College to determine the relation of dust load to time interval. On three different days when the machine was operating, samples of dusted seed were collected at the delivery spout at regular intervals. The dust load on each sample was then determined by means of the wash procedure and the results shown in Table VIII were obtained.

The data in Table VIII indicate that there was some degree of variation in the amount of dust adhering to seed treated at successive sample intervals during a continued machine run. There is nothing unusual in this and a similar variation would be expected in all machines sampled at intervals. The main point is that this particular machine was consistently failing to deliver seed with 2 oz. dust per bushel, but on an average was delivering it with just under 1.5 oz. of dust per bushel. Yet the storeman's records disclosed the season's turnover to be as follows:—

(a) Total quantity of seed wheat dusted in 1948:

Cross 7	.. ..	393 bushels
,,	.. ..	606 ,,
,,	.. ..	765 ,,
,,	.. ..	1,149 ,,
,,	.. ..	1,347 ,,
Fife Tuscan	..	462 ,,
,,	.. ..	501 ,,
Total	.. ..	5,223 bushels

(b) Total quantity organic-mercury dust used in 1948:
12 drums @ ½ cwt. = 6 cwt.

(c) Based on these figures the wheat seed delivered should therefore have had a fraction over 2.0 oz. per bushel.

TABLE VIII. DUST LOAD OF SAMPLES COLLECTED AT INTERVALS AS DELIVERED FROM ONE MACHINE
(all samples of Cross 7 variety)

26th February, 1948.		27th February, 1948.		3rd March, 1948.	
Time. (p.m.)	Dust Load. (oz.)	Time. (p.m.)	Dust Load. (oz.)	Time. (p.m.)	Dust Load. (oz.)
2·00	1·2	1·30	1·5	1·15	1·5
2·30	1·8	1·45	1·4	1·30	1·3
2·45	1·4	2·00	1·3	1·45	1·5
3·00	1·1	2·15	1·3	2·15	1·1
3·30	1·4	2·30	1·3	2·30	1·6
3·45	1·4	2·45	1·2	2·45	1·7
4·00	1·6	3·00	1·8	3·30	1·6
4·15	1·5	3·15	1·7	4·00	1·8
4·30	1·4	3·30	1·2	4·15	1·5
		4·00	1·3	4·30	1·4
		4·15	1·2	4·45	1·4

Standard error ± 0·22.
Significant difference 0·45 (5 per cent level); 0·29 (20 per cent level).

It would seem then that a substantial proportion of dust fails to adhere to the seed. The faults may lie in (1) the inadequacy of dust feed mechanisms; (2) insufficient mixing of dust and seed; (3) loss of dust from the machine. For instance in the star feed, revolving cylinder type machine with a forced draught over the baghole, it is believed that the fan blows a proportion of dust right out of the cylinder, and (4) losses occur by dust adhesion to the inner sack lining.

These observations on dusting machinery at present in use are of a preliminary nature, but it is believed that sufficient evidence has been brought forward to justify at an early date, a critical study of dusting machine efficiency. If a certain amount of dust loss is inevitable, the desired standard of approximately 2 oz. per bushel might result by using a calculated excess of dust but collecting any surplus not adhering to the grain by means of a gauze fitting, as is a feature of some of the machines in use. For small trial purposes the writer has frequently mixed by hand-shaking in a closed tin, wheat seed and an amount of dust calculated to 2 oz. per bushel rate. The dust under these conditions has all been retained by the seed which has also been shown by the wash procedure to carry the amount of dust added. Violent mechanical mixing of dust and seed in an enclosed system therefore appears to be

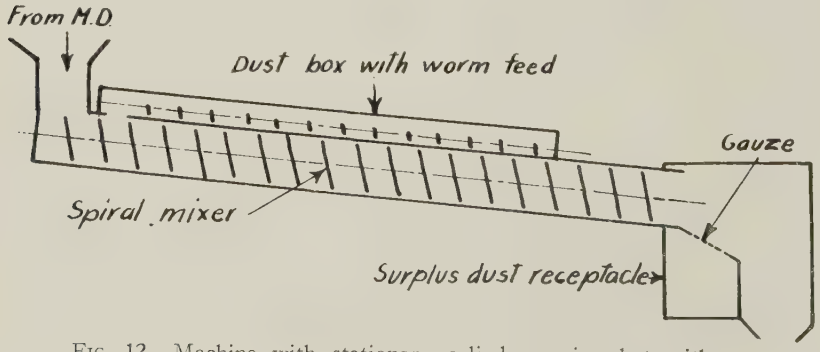

FIG. 12.—Machine with stationary cylinder casing but with an inner revolving spiral mixer.

a principle required in the mechanism of mixing but it is not a feature of the machines represented by Figs. 10, 11 and 12. A machine, however, has been developed by the Canterbury (N.Z.) Seed Co., Christchurch, which works on a principle involving vigorous mixing of seed and dust. A dust flow heavier than that necessary to give the required coverage is directed into the cylinder and any surplus not adhering is collected through the gauze mesh at the lower end of the cylinder. It is noteworthy that by incorporating a more vigorous mechanical action of dust and seed mixing, the above-named firm has developed a machine which has generally achieved good dust coverage.

Recent Advances Overseas

There are several dust machines in use in other countries which the writer has studied and which reveal the evidence of much greater efficiency than those machines generally available in New Zealand.

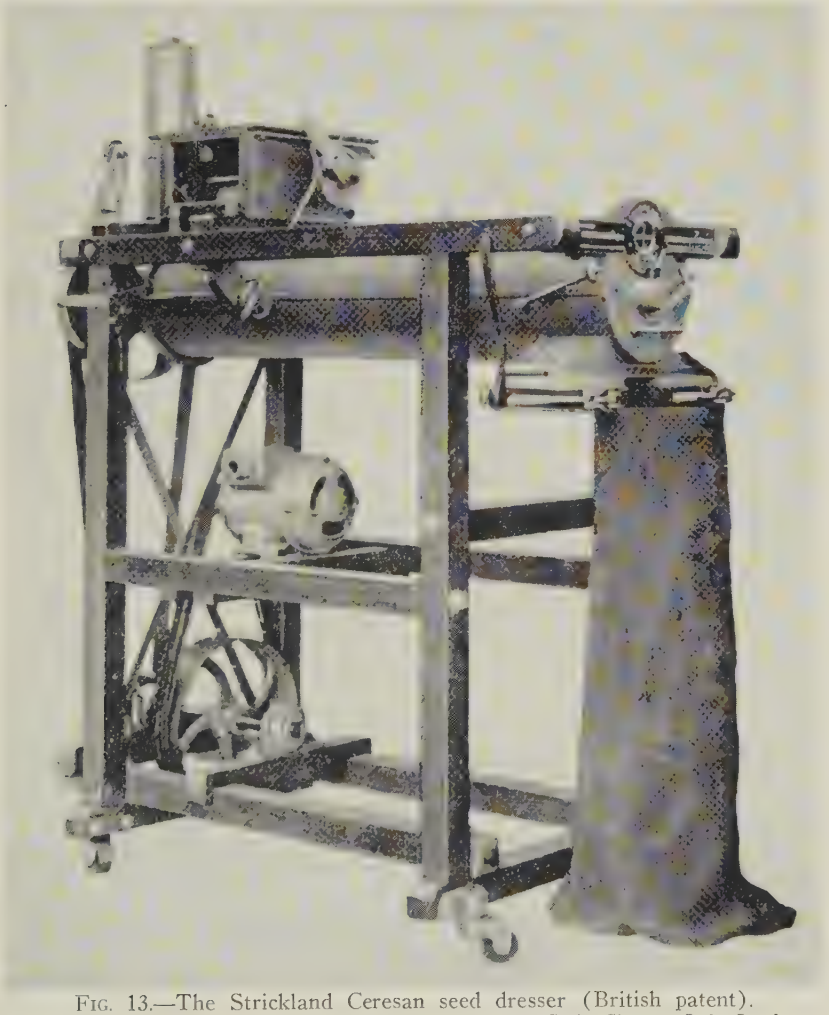

FIG. 13.—The Strickland Ceresan seed dresser (British patent).
Photo by courtesy Grain Cleaners Ltd., London.

Among them the "Hannaford-Carter" of South Australia and the "Strickland Ceresan" dressers of England are noteworthy. The Hannaford machine features a long mixing cylinder, cruciform-shaped in cross-section and within which a vigorous tumbling motion ensures good dust disinfectant coverage. The Strickland Ceresan machine is widely used in Britain and elsewhere and is a model of compact convenient design and high working capacity. Features of this type (Fig. 13) with which are associated demonstrated adequacy of dust coverage include an injecting device which delivers the dust into a glass-fronted box where powder and grain flow can be watched. The grain flow is controlled by a revolving cog with adjustable apertures and an automatic grain cut-out is synchronized with the dust injecting mechanism. Dust and grain are then delivered into the completely enclosed cylinder where fast revolving paddles complete the mixing process before the grain is delivered to the sacks tightly clamped to a feeding spout. Finally, reference can be made to new developments in grain-dusting machinery in the United States, e.g., the slurry method of seed treatment developed by the Dupont Company and described by Miles (1946). This method used initially with corn, involves the application of the chemical disinfectant to seed in the form of a water suspension or slurry instead of a dust. The water suspension is prepared using a specially formulated fungicide at the rate of 1 lb. per gallon of water, the powder remaining in suspension. The amount of water added to the seed by the slurry method is never more than about 0.5 per cent of the seed weight, and it is considered that in use the small proportion of water is not absorbed by the seed.

In his description of the method, Miles (1946) claims two advantages for the slurry method: (1) complete elimination of flying dust; and (2) accuracy and uniformity of the dosage of chemical applied.

Developed initially for corn seed treatment the slurry method is now offered by the Dupont Company for disinfectant treatment of wheat, rye, barley and oats. It must be emphasized that the slurry method necessitates the use of fungicides differing in chemical and physical properties from the standard organic mercurials used in dusting in New Zealand, and also necessitates the use of a new type of machine. It remains for future work to show whether the slurry method completely overcomes the problem of inadequate dust coverage on grain.

Possible Future Action in New Zealand

Should it be necessary to enforce action by those responsible in order to improve the dust load standards of seed grain, the suggestion has been made that improvement would be effected if a dust coverage standard were written into the Department of Agriculture seed certification requirements. The official seed Testing Station would then issue certification tickets endorsed according to whether or not the dust coverage was satisfactory. For this work either of the two testing procedures described earlier could be conveniently adopted by the Seed Testing Station. An even speedier method which at least can be used to differentiate between "well dusted" and "poorly dusted" lines could be applied in seed testing, using a low magnification type of dissecting microscope. This method has been used for quick general examination of samples. Well dusted lines of seed under this type of microscope show dust particles all over the grain surface, while inadequately dusted lines show dust particles only on the brush end among the hairs at that end of the grain or in the vicinity of the crease.

There are also chemical colour tests of value for routine checking purposes. With Ceresan-treated seed the test is as follows: 1 oz. of treated seed is shaken with 30 ml. or 1 oz. of methylated spirit and the filtered solution which is coloured violet blue is compared in intensity of colour with a standard made by treating a sample known to carry the correct Ceresan load. Where Agrosan has been applied, petrol is used for the colour test instead of methylated spirit, and the result determined according to the intensity of a red colour produced by the filtered solution.

The Microbiology Laboratory, Lincoln College, is in a position to offer a testing service to grain merchants who wish to obtain an indication of the dust coverage status of seed wheat. With little difficulty, however, the firm could arrange to make their own routine check once the procedures described in this paper had been learned by a suitably trained member of the staff. The problem remains for dusting machine manufacturers to give consideration to means of ensuring dust coverage efficiency.

ACKNOWLEDGMENTS

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STUDIES IN MONOZYGOTIC CATTLE TWINS
IV. UNIFORMITY TRIALS: GRAZING BEHAVIOUR

By JOHN HANCOCK, Ruakura Animal Research Station, Department of Agriculture, Hamilton

Summary

1. Observing the behaviour pattern of six sets of uniformly treated lactating monozygotic cattle twins for seven 24-hour periods throughout one season the following "Normal" values have been established:—

(a) Grazing time	410.9 min.
(b) Loafing time	194.6 "
(c) Lying down time	579.6 "
(d) Distances covered	3,038 yd.
(e) Number of defecations	12.2
(f) Number of urinations	10.12
(g) Number of drinks	3.65

2. The causes of variations in the behaviour pattern are discussed and it is concluded that individuality of the grazing animal, quality of the grass, and environment and inheritance interactions, are the most important factors.

3. The relative usefulness of monozygotic twins in research on grazing habits has been estimated, resulting in the following twin efficiency values.

(a) Grazing time	72
(b) Loafing time	6
(c) Lying down time	3
(d) Distances covered	3
(e) Number of defecations	8
(f) Number of urinations	1
(g) Number of drinks	5

4. Detailed observations on the grazing and rumination habits of two sets of monozygotic twins over one 24-hour period yielded following results:—

(a) Total number of bites (grazing)	23,966
(b) Average rate of grazing (bites per min.)	51.3
(c) Duration of rumination	324.3
(d) Total number of bites (rumination)	17,117
(e) Ratio of $\frac{\text{rumination (min.)}}{\text{grazing}}$	0.75

5. The pronounced differences shown to occur in the grazing and rumination habits of dairy cattle of different genetical make-up in the same environments are discussed in the light of their practical significance.

INTRODUCTION

As one of the series of uniformity trials to which attention has already been drawn (1), a number of observations on the grazing behaviour of monozygotic heifers has been made. The study is of special value to cattle workers in New Zealand in view of the almost complete dependence of dairy cattle upon pasture in this country. The study is the first of its kind to have been made in New Zealand, and one of the few made anywhere. The results, therefore, should be of interest quite apart from the specialized twin-uniformity aspects of the work, since information on grazing behaviour is basically important to an understanding of the many and varied grassland problems involving the welfare of the dairy cow.

Very limited data on the subject exist. Hodgson (2) reported that Holstein cattle, under a system of rotational grazing, grazed for six and a half to seven hours daily, and that under continuous grazing they spent seven to seven and a half hours so employed. His observations were made only during daylight from 6 a.m. onwards. Atkeson *et al.* (3), working with a limited number of dairy cows and making their observations only during the 12 daylight hours, found that milking cows on good pastures grazed for shorter time than cows on poorer or medium pastures. Dry cows and yearling heifers grazed for seven hours, loafed for four hours and lay down for 13 hours on an average for a 24-hour period. Johnston-Wallace and Kennedy (4) observed in great detail four nursing cows of a beef breed on four 24-hour periods and concluded that they grazed on an average for approximately seven and a half hours, loafed for four and a half hours and lay down for 12 hours, and ruminated for almost seven hours. Seath and Miller (5) investigated the influence of air temperature on the grazing habits of dairy cows and concluded that hot weather (85 - 86°F. max.) lowered the grazing time by one hour compared with cool weather (72°F. max.). Such conditions also altered the ratio of $\frac{\text{day grazing}}{\text{night grazing}}$ from approximately $\frac{1}{1}$ during the cool days to approximately $\frac{1}{3}$ during the hot days.

It is noteworthy that none of these authors has given any data as to the variation occurring between cows on the same day. Such information is important if the soundness of the conclusions is to be assessed.

Material and Methods

For the present studies, the material used has been described in a previous paper (1). All cows had calved and observations involved six sets of monozygotic heifers all grazing together. The six sets employed were T1 - T2, T11 - T12, T13 - T14, T17 - T18, T23 - T24, and T31 - T32. Choice was governed by two factors:

(a) The calving dates for the members of the same set had to be reasonably close.

(b) The inclusion of cows of widely differing theoretical feed-requirement levels was thought desirable.

Since, apart from body-size, production mainly determines the feed requirements of dairy cows, the experimental animals were chosen so as to include good, medium, and poor producers. Selection had to be made in the beginning of the season when the production qualities of the cows were not known with certainty. However, that the objectives were attained is indicated by the yield data in Table I. The figures quoted are the mean daily productions for three days of which the observation day was the mid-point. Calving dates and body weights are also given in the same Table. The body weights at time of observation are smoothed weights calculated from five consecutive weekly weighings.

The aim was to provide similar pasture conditions throughout the season in order to leave the production levels of the cows and the weather conditions as the only variable factors. This, however, proved somewhat difficult to achieve during the dry period in the summer, but

TABLE I. PRODUCTIONS AND LIVE-WEIGHTS

Cow No.	Calving Date.	8/11/46.			13/12/46.			11/1/47.			5/2/47.			25/2/47.			10/4/47.			8/5/47.			28/6/47.		
		1.	2.	3.	1.	2.	3.	1.	2.	3.	1.	2.	3.	1.	2.	3.	1.	2.	3.	1.	2.	3.	1.	2.	3.
T 1	11/8/46	23·2	1·16	666	19·8	1·07	686	18·3	1·00	705	19·9	1·06	718	17·3	·97	742	17·1	1·03	770	14·0	·97	788	—	—	833
T 2	17/8/46	24·1	1·29	664	21·2	1·14	685	19·9	1·06	707	18·5	·94	718	20·3	1·15	735	19·9	1·19	762	16·9	1·07	779	—	—	833
T11	19/8/46	16·8	·93	614	15·6	·92	633	15·2	·87	667	17·9	1·01	670	16·6	·99	673	15·2	·98	697	13·8	·90	704	—	—	695
T12	17/9/46	16·4	·98	629	14·5	·84	669	14·1	·77	693	16·7	·92	696	16·1	·93	716	15·2	·96	751	13·3	·86	763		-	796
T13	20/8/46	19·2	1·05	706	14·9	·83	751	13·9	·76	758	14·3	·79	770	14·1	·81	787	12·7	·79	807	10·2	·66	831	- -	—	850
T14	15/8/46	20·1	1·07	704	14·2	·76	746	14·5	·77	755	15·2	·79	765	13·4	·77	780	11·8	·70	812	9·7	·62	842	—	—	871
T17	27/8/46	25·1	1·62	824	23·5	1·37	848	20·9	1·24	865	22·8	1·28	865	21·5	1·29	881	20·9	1·33	893	19·3	1·27	906			957
T18	14/8/46	26·0	1·48	840	22·8	1·38	863	16·5	·97	874	22·5	1·29	877	21·6	1·32	885	20·9	1·38	883	18·7	1·30	914	—		968
T23	16/8/46	—*	—	722	—	—	761	—	—	783	—	—	789	—	—	809	—	—	847	—	—	854	—	—	853
T24	3/9/46	—	—	688	—	—	673	—	—	715	—	—	726	—	—	739	—	—	767	—	—	790	—	—	766
T31	17/9/46	3·4	·16	596	1·5	·09	671	—	—	704	—	—	729	—	—	755	—	—	782	—	—	784	—	—	780
T32	16/9/46	4·0	·18	631	2·3	·12	686	—	—	719	—	—	728	—	—	755	—	—	787	—	—	792	—	—	796

1 = pounds milk. 2 = pounds butterfat. 3 = body weight pounds (see test for explanation). * Where productions not shown animals non-lactating.

as can be judged by the pasture notes in Table II, the animals were provided with a sward which was reasonably similar in quantity on each observation day. The quality, however, fluctuated widely. During the spring and autumn the grass was lush and soft with relatively low dry matter content, whereas the sward in the summer was hard and fairly mature. Such changes in the quality of the pasture involves a digestibility difference of approximately 20 per cent and represents a common trend that occurs regularly year after year in New Zealand.

Table II. Pasture Conditions

Date.	Brief Description.	General Quality.
8/11/46	Ryegrass, cocksfoot and Yorkshire fog predominant. Very little white clover. 30 per cent of area covered with dung and urine patches of which 5-7 in. tall ryegrass was coming to head. The remainder covered with 2-3 in. high, and somewhat hard stemmy grasses.	Good
13/12/46	Ryegrass, Yorkshire fog and Poa pratensis 4-5 in. high predominant with white clover undergrowth partly in flower. A few fully developed ryegrass heads up to 12 in. in evidence. Very green and succulent.	Excellent
11/1/47	Ryegrass, Yorkshire fog and white clover 4-15 in. predominant. Sward somewhat patchy and hardening.	Very good
5/2/47	Cocksfoot and Yorkshire fog 4-6 in. high predominant. A good undergrowth of flowering white clover. Some patches of grasses 10-12 in. in seedhead stage. Very little ryegrass evident. Fairly hard and stemmy.	Fair
25/2/47	Cocksfoot and Yorkshire fog and white clover dominant 2-5 in. Pasture patchy with some grass up to 30 in. Clover mostly past flowering stage but fairly hard and dry.	Fair
10/4/47	Ryegrass and clover dominant 2-6 in. Green and succulent except for dung patches consisting of 8-10 in. cocksfoot.	Good
8/5/47	Ryegrass and clover dominant 4-8 in. Some white clover flowerheads. Green fast growing sward except for dung patches covered by rank cocksfoot 12 in. high.	Very good
29/6/47	Ryegrass and cocksfoot dominant with good amounts of white clover still evident 4 in. high. Rank cocksfoot in patches up to 10 in. Green and succulent.	Excellent

During the period from mid-February to mid-April, it was necessary to supplement pasture with silage and roots. However, two days before the dates set for the grazing trial at the end of February and the beginning of April, the silage was withdrawn and the cows were allowed to graze on adequate pasture similar to that used during the subsequent trial in order to condition them to a "pasture only" diet. From general observations this procedure did not seem to upset the grazing behaviour in any way.

It was necessary to use four different paddocks but the type of sward in all these was very similar. The paddocks were roughly one acre in extent and of the dimensions 60 by 80 yd. There was no shelter in the paddocks which were fairly open to the southerly and south westerly winds prevailing especially in the spring and early summer. Water was available in self-feeding troughs at all times.

TABLE III. OBSERVATIONS ON WEATHER

Date.	Max. °F.	Min. °F.	Grass Min. °F.	Rain (In.)	Wind Direction.	Force.	Remarks.
8/11/46	56·5	43·2	24·4	·08	SW	4	Rain showers at 8.30, 10.30 and 12 a.m., 2, 5, 7 p.m.
13/12/46	64·0	52·8	46·0	·04	WSW	3	Overcast. Showers in afternoon.
11/1/47	69·1	57·4	47·2	·09	WNW	1	Shower at 8 a.m. Otherwise fair. Cows fidgety—flies in afternoon.
5/2/47	77·7	46·9	39·0	—	—	0	Morning, overcast. Sunshine in the afternoon. Light breeze.
25/2/47	74·1	48·5	36·9	—	W	1	Fog in morning lifted at 9.20 a.m. Cool in afternoon—wind W at 5.00.
10/4/47	67·5	47·5	43·8	—	SSW	2	Sun shining up till 1.00. Clouded over in afternoon. Cool breeze.
8/5/47	64·8	49·5	47·3	·36	NW	2	Overcast, heavy passing showers in morning. Cloudy in afternoon—showery.
19/6/47	51·7	22·3	17·9	—	SSE	1	Frost in the morning. Fine day no cloud from 10.30 a.m.

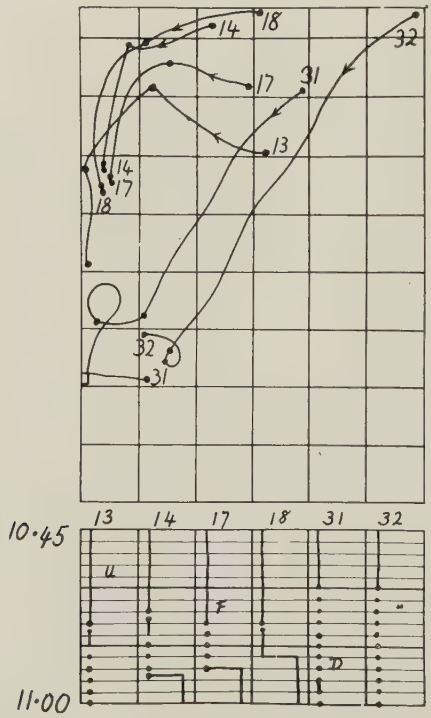

FIG. 1.—Facsimile of working sheet showing the method of recording used in these trials (see text).

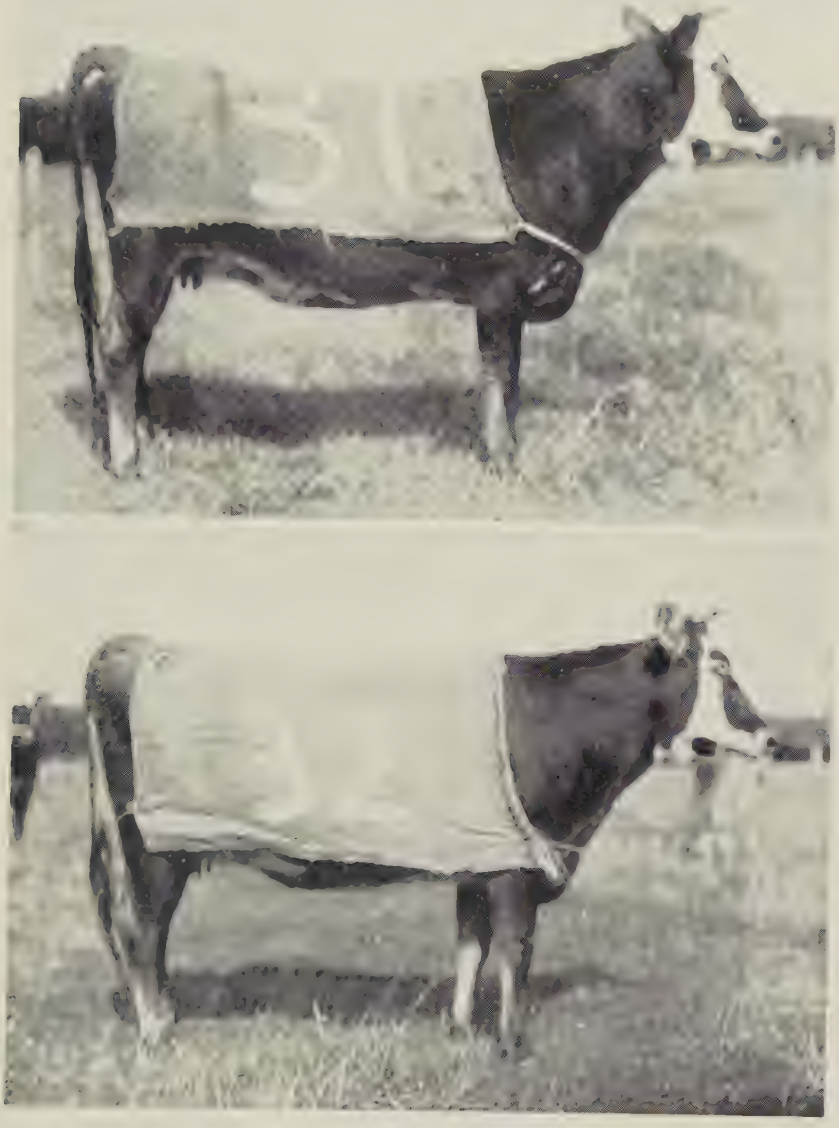

FIG. 2.—One of the six sets of monozygotic twins used in this experiment.

Weather

As the trials were extended to cover the whole season, it is only natural that a great variety of weather conditions was encountered. The weather on 8 November 1946, for instance, was as cold, wet and windy as any day during the season, whereas 5 February, 1946, was one of the hottest days of the summer. A summary of the weather conditions is given in Table III. These data have been compiled from the daily weather records of the Station.

Recording Technique

In order to facilitate the recording of the various activities, special forms were designed which almost obviated the use of letters or figures. Using these forms one man was able to observe and record comfortably the activities of the six cows. A facsimile of a working sheet which was of foolscap size is shown in Fig. 1. The following description will clarify the method of recording. The sheet covers a quarter hour period from 10.45 a.m. to 11.0 a.m. for the cows T13, T14, T17, T18, T31 and T32. The square top portion of the sheet represents the paddock which had been divided by two foot long stakes into 10 x 10 squares. The course each cow followed when walking in the paddock was approximated on the sheet and her exact position was plotted at five-minute intervals. The point representing the cow's position at the end of 15 minutes period was transferred to the next sheet. The lower portion of the sheet was divided vertically into six columns—one for each cow and transversally into 15 divisions each representing one minute. A period of grazing was annotated by an unbroken line running vertically on the left side of the column of the respective cow. When a cow was not grazing but still standing or walking this line was broken by dots. The time spent lying down was represented by a line on the right side of the column transversing the appropriate number of minutes. The occasions of defecations, urinations and drinking, were annotated by the letters, F, U and D respectively in the appropriate column and time space. The time periods spent in the various activities were recorded to the nearest half minute.

Because the members of the same sets of twins in all cases were so similar in appearance that they could not be distinguished from each other, it was necessary to cover them with light sacks on which their respective numbers had been painted (Fig. 2). During the daylight hours the observers sat on stands 6 ft. high (Fig. 3) from which a commanding view of the paddock could be had. During the darkness,

FIG. 3.—Observing grazing behaviour during daytime.

it was necessary to walk in the paddock and, with the occasional use of a flashlight, ascertain the positions and activities of the cows. Frequently the moonlight was strong enough to make the use of the flashlight unnecessary. The animals had previously been handled and were, therefore, very quiet and took no notice of the observers.

On the occasion when the rumination habits were studied it was necessary to employ one observer to each cow and in addition a recorder.

Data Recorded

The animals were observed on eight days at approximately monthly intervals, each occasion covering a 24-hour period. The following data were collected on each day for each cow:—

(1) Time spent grazing.
(2) Time spent standing or walking, not grazing (loafing).
(3) Time spent lying down.
(4) The distance walked.
(5) Number of defecations.
(6) Number of urinations.
(7) Number of drinks.

In addition the following data were obtained as the result of observation on two sets of twins during one 24-hour period.

(8) Number of bites of grass.
(9) Time spent ruminating.
(10) Number of boluses ruminated.
(11) Number of bites to each bolus.

Results

All the different aspects of this work such as the influence of weather, season and individuality on the grazing behaviour of dairy cows will be discussed together under the headings of the specific activities. The trial on 27 June 1947, at which time all cows had been dried off, is not included in the averages.

Time Spent Grazing, Loafing and Lying Down

Environment

The average values obtained for these activities are shown in Table IV. The cows spent on an average 410.9 minutes in grazing.

Table IV. Grazing, Loafing and Lying Times
(Mean Values for 12 cows)

Date.	Grazing Time.		Loafing Time.		Lying Time.	
	Mean.	Per cent of available time.	Mean.	Per cent of available time.	Mean.	Per cent of available time.
8/11/46	410·8	34·7	183·5	15·5	590·6	49·8
13/12/46	457·5	38·6	90·2	7·6	637·3	53·8
11/1/47	431·7	36·4	194·7	16·4	558·6	47·1
5/2/47	373·3	31·5	252·2	21·3	559·5	47·2
25/2/47	374·5	31·6	155·6	13·1	654·9	55·3
10/4/47	381·4	32·2	184·5	15·6	619·0	52·2
8/5/47	446·8	37·7	301·2	25·4	437·1	36·9
Average	410·9	34·7	194·6	16·4	579·6	48·9
29/6/47	422·9		293·5		723·6	

The differences between days are significant on the one per cent level, the difference required for significance being 23.4 minutes and 17.5 minutes at the one per cent and five per cent levels respectively. It can thus be seen that there were three days with long, three days with short, and one day with intermediate, grazing times. As the cows grazed approximately the same length of time at the peak of lactation (13 December 1946) as towards the end (18 May 1947) it does not seem likely that the stage of lactation markedly influenced the grazing time. It is, therefore, logical to assume that the depressed grazing times between these days and prior to 13 December 1946 were due to weather conditions or to the quality of the grass. The weather on 8 November 1946 was certainly such that lowering of grazing time could be expected, in that frequent cold showers with blustering winds caused the cows to drift to the fence furthest from the direction of the wind, where they remained motionless with crouched backs for long periods, which otherwise might have been occupied in grazing. The reason for the depressed grazing time during the days of 5 February, 25 February, and 10 April is, however, not easily found. It is certainly true that the first two days were comparatively warm for New Zealand conditions which may be thought to have depressed the grazing time, but the third day was quite cool, and yet the grazing time was hardly longer. These dates coincided, however, with a summer drought when the quality of the grass generally tends to deteriorate in that the increase in the fibre content makes the grass less palatable to cattle. On the other hand the dry-matter content of the grass increases under such conditions and it is, therefore, conceivable that the cows were able to satisfy their appetites in a shorter time than if they had been grazing on lush sward.

It remains to be pointed out that the grazing time on 29 June 1947 when all cows had been dried off, was higher than the average for all days during the lactation period. However, the grazing conditions on this day were ideal both from a weather and pasture point of view.

The average loafing time was 194.6 minutes and average lying down time, 579.6 minutes. The differences between days for these activities are significant at the one per cent level. The required differences are 30.6 minutes and 37.1 minutes at the one per cent level and 22.8 minutes and 27.8 minutes on the five per cent level respectively, for loafing and lying down times. It is, however, very difficult to find a logical explanation for the differences noted. The two days showing the longest grazing time were associated on the one hand with the shortest loafing time (on 13 December 1946), and on the other hand with the longest loafing time (on 8 May 1947). Again the two days showing the shortest grazing periods, viz., 5 and 25 February 1947, were associated with long and short loafing periods respectively. The lying down times show similar inexplicable variations in that long grazing periods were associated with short lying down periods as on 8 May or with long ones as on 25 February. Table II shows that on an average 34.7 per cent of the available time was spent in grazing, 16.4 per cent. in loafing and 48.9 per cent in lying down. The cows thus divided their day through these activities roughly into the proportions 2:1:3.

Considering all three activities together, the following generalization seems justified. Provided that the length and density of the sward are kept constant the time that dairy cows on pastures in New Zealand spend in grazing is determined mainly by the quality of the grass and, to a lesser extent, by weather conditions. The stage of lactation seems

to have little influence on the grazing time. The cows require to lie down approximately 50 per cent of the time spent in the paddock. If the grazing time is shortened for any reason this is reflected in a longer time spent in loafing rather than increased lying down time.

Distribution

The distribution throughout the day of the various activities shows some interesting features with practical implications. Table V shows that slightly less than 60 per cent of the total grazing time is spent between 7 a.m. and 3 p.m. and slightly more than 40 per cent between 5 p.m. and 4.45 a.m. This ratio was fairly constant under all weather and pasture conditions.

Table V. Distribution of Grazing Time during Periods between Milkings (Mean Values for 12 Cows)

Date.	7 a.m.-3 p.m.		5 p.m.-4.45 a.m.	
	Minutes.	Per cent.	Minutes.	Per cent.
8/11/46	236·5	57·6	174·3	42·4
13/12/46	248·0	54·2	209·5	45·8
11/1/47	262·2	60·7	169·5	39·3
5/2/47	216·0	57·9	157·3	42·1
25/2/47	219·5	58·6	155·0	41·4
10/4/47	226·1	59·3	155·3	40·7
8/5/47	268·1	60·0	178·7	40·0
Average	239·5	58·3	171·4	41·7

For the sake of convenience it is common practice in New Zealand to confine the milking cows to a relatively small area close to the milking shed during the night. In view of the 60/40 division of grazing time found in these trials it is possible that cows under such circumstances are not able to obtain maximum feed-intake. However, practical advice on this point cannot be given as it is not known to what extent dairy cows are able to modify their grazing habits to suit various artificially shaped conditions. Warmer weather such as on 5 and 25 February 1947 did not increase the time spent in grazing in the cooler part of the day (5 p.m. to 4.45 a.m.) relative to the time spent in grazing during the warmer part (7 a.m. to 3 p.m.). This fact is further evidence for the correctness of the previous statement that the prevailing high temperatures did not cause the observed drop in the total grazing times on these days.

When the available time is divided into day and night periods, it is seen (Table VI) that almost 85 per cent of the total grazing time was on an average spent during daylight and only 15 per cent during darkness. The ratio between actual grazing times on these periods remained fairly constant until 10 April 1947 in spite of the progressively shorter days. However, on and after this date, both the actual and relative times occupied in grazing during darkness increased markedly. This is well illustrated in Fig. 4 and Table VI which show the distribution throughout the 24 hours of the various activities under consideration. It is quite noticeable that the cows in these trials were conditioned to stop grazing soon after darkness fell. This habit, however, was broken by 10 April 1947 when the hours of daylight became so short that the cows did not have time to satisfy their appetites during this period and therefore extended their afternoon grazing beyond nightfall.

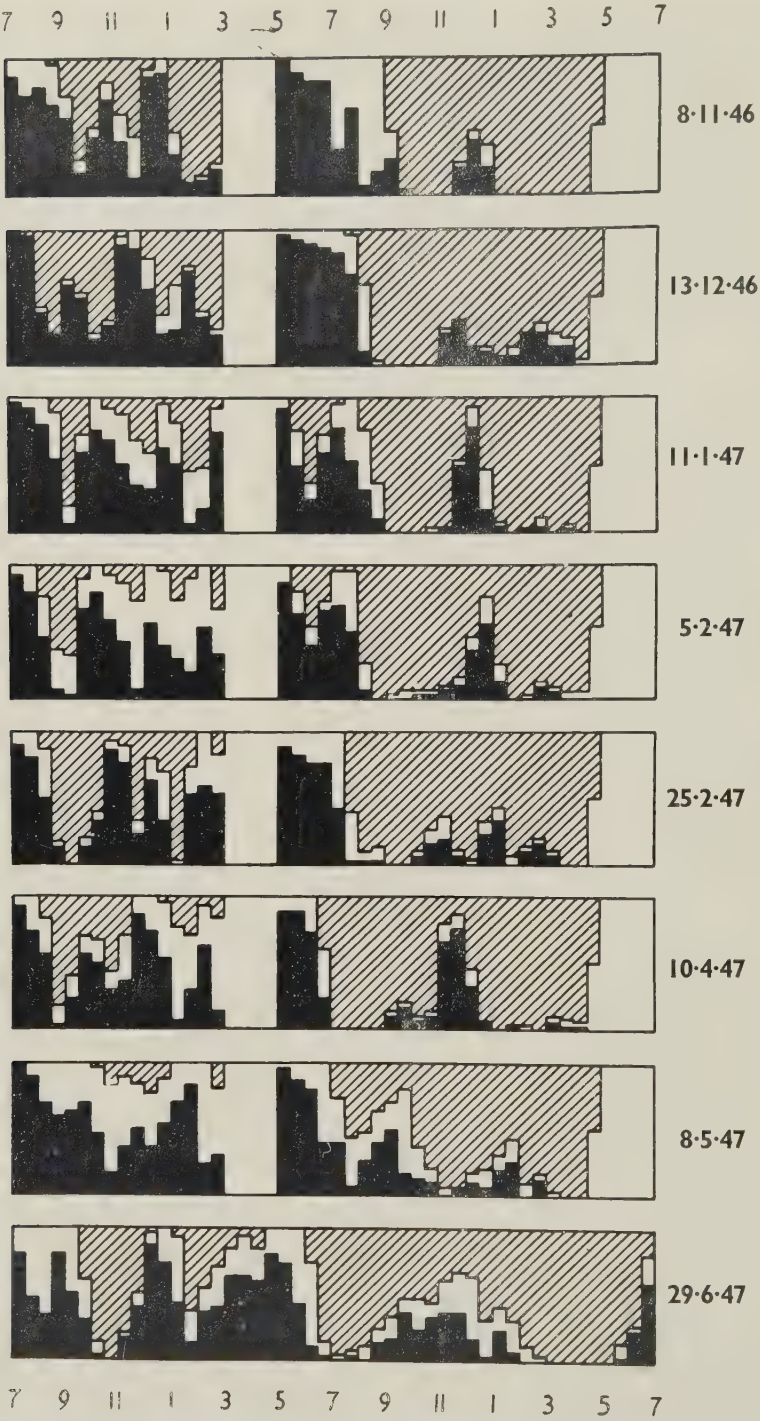

FIG. 4.—Diagram showing the distribution of grazing, loafing and lying over each 24-hour period. Black areas represent grazing, white represent loafing, and crosshatched, lying.

Table VI. Distribution of Grazing Time during Periods of Daylight and Darkness
(Mean Values for 12 cows)

Date.	Available time min.		Daylight.		Darkness.	
	Daylight.	Darkness.	Min.	Per cent.	Min.	Per cent.
8/11/46	645	540	355·5	86·5	55·3	13·5
13/12/46	675	510	407·8	89·1	49·7	10·9
11/1/47	690	495	379·2	87·8	52·5	12·2
5/2/47	670	515	332·6	89·1	40·7	10·9
25/2/47	630	555	329·8	88·1	44·7	11·9
10/4/47	570	615	302·0	79·2	79·4	20·8
8/5/47	540	645	325·0	72·7	121·8	27·3
Average	631	554	347·4	84·5	63·5	15·5
29/6/47	630	810	303·8	71·8	119·1	28·2

Another point brought out in this diagram is the cyclic pattern of grazing shown by dairy cows which already has been pointed out by Atkeson *et al.* (3). There were generally six cycles of grazing: four between the morning and afternoon milkings, one immediately after the cows were let out on the pasture at 5 p.m., and one (sometimes two) during the night. On three occasions, on 11 January, 5 February and 25 May 1947 the period subsequent to the afternoon milking was broken into two distinct cycles. The cause for this cyclic pattern of grazing will be discussed later in connection with the results from the investigation on the rumination habits. Meanwhile it is sufficient to draw attention to the similarities and differences in this pattern when lactating cows are compared with dry ones. On 29 June 1947, when all the cows were dry, the four cycles during the day were still apparent in spite of the fact that the whole grazing routine was not on this occasion disrupted by the removal of the cows from the pasture for milking. This indicates that the long period of relative inactivity between midnight and early morning alone, without the addition of the enforced abstention from grazing imposed on the cows by milking, may have initiated the cyclic pattern.

Table VII shows that approximately 50 per cent of the available time between 7 a.m. and 3 p.m. (480 minutes) was on an average spent in grazing. It seems that even under ideal grazing conditions dairy

Table VII. Occupation during Periods between Milking (per cent)
(Mean Values for 12 Cows)

Date.	7 a.m.-3 p.m.			5 p.m.-4.45 a.m.		
	Grazing.	Loafing.	Lying.	Grazing.	Loafing.	Lying.
8/11/46	49·3	14·7	36·1	24·7	16·0	59·2
13/12/47	51·7	7·9	40·5	29·7	7·4	62·9
11/1/47	54·6	24·2	21·1	24·0	11·1	64·8
5/2/47	45·0	37·3	17·7	22·3	10·4	67·3
25/2/47	45·7	16·3	38·0	22·0	11·0	67·0
10/4/47	47·1	28·5	24·4	22·0	6·8	71·2
8/5/47	55·9	37·8	6·4	25·3	17·0	57·7
Average	49·9	23·8	26·3	24·3	11·4	64·3

Milking times—4.45-7 a.m.; 3-5 p.m.

cows do not spend much more than half of the time between morning and afternoon milkings in actual grazing. The rest of this time is partly used for searching for food, partly for rest and rumination.

Of the time period 5 p.m. - 4.45 a.m. only approximately 25 per cent was occupied in grazing. The cows grazed 55 per cent of the daylight (Table VIII) and only 11.5 per cent of the hours of darkness.

The distribution of loafing through the 24 hours is shown in Tables IX and X.

TABLE VIII. OCCUPATION DURING PERIODS OF DAYLIGHT AND DARKNESS (PER CENT)
(Mean Values for 12 Cows)

Date.	Daylight.			Darkness.		
	Grazing.	Loafing.	Lying.	Grazing.	Loafing.	Lying.
8/11/46	55·1	18·0	26·8	10·2	12·4	77·3
13/12/46	60·4	10·4	29·2	9·7	3·9	86·4
11/1/47	55·0	24·2	20·8	10·6	5·6	83·8
5/2/47	49·6	33·2	17·2	7·9	5·8	86·3
25/2/47	52·3	18·5	29·1	8·1	7·0	85·0
10/4/47	53·0	26·6	20·4	12·9	5·4	81·7
8/5/47	60·2	34·1	5·7	18·9	18·2	63·0
Average	55·0	23·3	21·7	11·5	8·6	79·9
29/6/47	48·2	23·9	27·8	14·7	17·6	67·7

TABLE IX. DISTRIBUTION OF LOAFING TIME IN PERIODS BETWEEN MILKING
(Mean Values for 12 Cows)

Date.	7 a.m.-3 p.m.		5 p.m.-4.45 a.m.	
	Min.	Per cent. of Total.	Min.	Per cent. of Total.
8/11/46	70·4	38·4	113·1	61·6
13/12/46	37·8	41·9	52·4	58·1
11/1/47	116·3	59·7	78·4	40·3
5/2/47	179·0	71·0	73·2	29·0
25/2/47	78·1	50·2	77·5	49·8
10/4/47	136·9	74·2	47·6	25·8
8/5/47	181·4	60·2	119·8	39·8
Average	114·4	58·8	80·2	41·2

TABLE X. DISTRIBUTION OF LOAFING TIME IN PERIODS OF DAYLIGHT AND DARKNESS
(Mean Values for 12 Cows)

Date.	Available time in Min.		Daylight.		Darkness.	
	Daylight.	Darkness.	Min.	Per cent.	Min.	Per cent.
8/11/46	645	540	116·3	63·4	67·2	36·6
13/12/46	675	510	70·3	77·9	19·9	22·1
11/1/47	690	495	167·0	85·8	27·7	14·2
5/2/47	670	515	222·2	88·1	30·0	11·9
25/2/47	630	555	116·8	75·1	38·8	24·9
10/4/47	570	615	151·4	82·1	33·1	17·9
8/5/47	540	645	184·0	61·1	117·2	38·9
Average	631	554	146·9	75·5	47·7	24·5
29/6/47	630	810	150·8	51·4	142·7	48·6

It will be seen that on an average the total loafing time is divided in almost exactly the same proportions (60:40) as the grazing times between 7 a.m. and 3 p.m., and 5 p.m. and 4.45 a.m., periods. However, this seems to be a mere coincidence as this ratio varies greatly on the different days. Of the total loafing time 75 per cent was distributed over the period of daylight and 25 per cent over the period of darkness. Relative to time spent in grazing the cows thus seem to loaf more during the night than during the day. Table VII shows that the time spent loafing from 7 a.m. to 3 p.m. relative to the total available times, is twice as long as the time spent in this activity from 5 p.m. to 4.45 a.m. This again applies only to the average with great variations from day to day. Loafing occupied 23.8 per cent of the daylight hours, but only 11.4 per cent of the hours of darkness (Table VII).

Table XI shows that on an average only just over 20 per cent of the total time spent in lying down fell within the 7 a.m. to 5 p.m. period, and slightly more than approximately 24 per cent within the daylight period. From Table XII, about 26.3 per cent of the time between 7 a.m. and 5 p.m. was spent lying down while 64.3 per cent between 5 p.m. and 4.45 a.m. was spent in this activity (Table VII) whereas the corresponding values for the periods of daylight and darkness were 21.7 and 79.9 per cent (Table VIII).

Table XI. Distribution of Lying Time during Periods between Milkings
(Means for 12 Cows)

Date.	7 a.m.-3 p.m.		5 p.m.-4.45 a.m.	
	Min.	Per cent.	Min.	Per cent.
8/11/46	173·1	29·3	471·5	70·7
13/12/46	194·2	30·5	443·1	69·5
11/1/47	101·5	18·2	457·1	81·8
5/2/47	85·0	15·2	474·5	84·8
25/2/47	182·4	27·9	472·5	72·1
10/4/47	116·9	18·9	502·1	81·1
8/5/47	30·5	7·0	406·6	93·0
Average	126·3	21·8	453·3	78·2

Table XII. Distribution of Lying Time during Periods of Daylight and Darkness
(Means for 12 Cows)

Date.	Available time. Min.		Daylight.		Darkness.	
	Daylight.	Darkness.	Min.	Per cent.	Min.	Per cent.
8/11/46	645	540	173·1	29·3	417·5	70·7
13/12/46	675	510	196·9	30·9	440·4	69·1
11/1/47	690	495	143·8	25·7	414·8	74·3
5/2/47	670	515	115·2	20·6	444·3	79·4
25/2/47	630	555	183·4	28·0	471·5	72·0
10/4/47	570	615	116·5	18·8	502·5	81·2
8/5/47	540	645	31·0	7·1	406·1	92·9
Average	631	554	137·1	23·7	442·5	76·83
29/6/47	630	810	175·4	24·2	548·2	75·

The daily variations in the distribution of the loafing and lying down times were great, and difficult to interpret. However, it seems obvious that the lying down period on 11 January, 5 February, and 8 May 1947 which divided the customary grazing period after the evening milking into two distinct portions was in each case due to the fact that the cows did not have a long rest during the day. On the first of these days the cows were irritated in a high degree by flies and on the second day were probably too warm for comfort. Conditions such as these may thus alter the normal behaviour patterns of dairy cows on pasture.

Considering the distribution of all three activities together, it seems now established that the habits of dairy cows in New Zealand are essentially diurnal. This is perhaps best illustrated by the fact that the ratio of grazing : loafing : lying down was approximately 5 : 2 : 2 during daylight compared with 1 : 1 : 8 during darkness.

Individuality

On *a priori* grounds it may be assumed that the grazing habits of a cow depend at least partly on her individuality. In this connection the concept of individuality is an aggregate of various factors including, for instance, the food requirements for maintenance, production, growth and work, the ability to digest and utilize the ingested food, the rate of grazing as measured by bites per time unit and the amount of grass obtained in each bite, and the cow's reaction to the inclemency of weather. From the point of further investigations on the influence of various environmental factors on the grazing habits of dairy cows, it is, of course, of greatest importance that possible error due to variations between cows should be eliminated. One of the main objects of the work presented here was, therefore, to find out whether individuality-determined differences in grazing habits do in fact exist and, if this was confirmed, to measure the magnitude of such differences.

Generally, it is convenient to detect and measure individuality by repeated measurements of the characteristic under consideration in several animals and express the results either as the variance ratio $\frac{\text{between animals}}{\text{within animals}}$ or in the form of an intra-class correlation coefficient. However, if this procedure is to yield entirely correct results, it is necessary that the environment on the various sampling occasions should be kept as constant as possible. In measuring the grazing habits of dairy cows this condition cannot be fulfilled as the three main variables—weather, pasture, and the interaction between cows and these two factors —are difficult or impossible to control.

By using monozygotic twins these difficulties were entirely overcome as sampling errors can be measured by the within-set differences and by the days x within-set interaction. Tables XIII, XIV, and XV, have been prepared to show the grazing, loafing, and lying down, times obtained for each animal on the eight trial days. The mean figures which do not include data obtained on 29 June 1947 when the cows were dry, for the three activities, abstracted in Tables XVI, XVII and XVIII, reveal two important points.

(1) The differences within sets of twins are almost negligible, averaging only 4 min. for grazing, 7 min. for loafing, and 8 min. for lying down.

Table XIII. Time Spent Grazing (min.)

Date.	T1	T2	T11	T12	T13	T14	T17	T18	T23	T24	T31	T32
8/11/46	448·5	370·5	472·5	456·5	376·5	427·5	465·5	494·0	264·0	325·0	399·5	430·0
13/12/46	427·5	413·5	520·0	531·5	410·0	448·5	488·0	489·5	421·0	442·0	443·5	455·5
11/1/47	403·0	424·0	468·0	440·0	410·5	405·5	502·5	461·5	387·0	397·5	358·0	422·5
5/2/47	386·5	414·5	412·5	396·5	362·0	353·0	447·5	437·0	296·0	281·0	355·5	337·0
25/2/47	366·0	384·5	408·5	448·0	363·5	337·0	428·5	456·0	312·5	314·5	356·5	318·0
10/4/47	357·5	349·5	444·5	411·0	372·0	377·5	464·0	434·5	318·5	291·5	365·5	391·0
8/5/47	433·0	433·5	496·5	475·0	416·0	452·5	576·5	539·0	363·5	346·0	419·5	410·0
Average	403·1	398·6	460·4	451·2	387·2	400·2	481·8	473·1	337·5	342·5	399·7	394·9
Per cent of available time	34·0	33·6	38·9	38·1	32·7	33·8	40·7	39·9	28·5	28·9	33·7	33·3
29/6/47	379·5	412·0	427·5	450·5	422·0	451·0	486·5	450·5	342·5	329·0	477·5	446·0

Table XIV. Time Spent Loafing (min.)

Date.	T1	T2	T11	T12	T13	T14	T17	T18	T23	T24	T31	T32
8/11/46	147·5	204·5	120·0	111·0	209·5	212·5	183·0	144·0	238·0	299·5	165·5	167·5
13/12/46	76·5	85·5	109·5	109·5	44·0	83·0	74·0	46·0	117·0	168·0	80·0	89·0
11/1/47	163·0	178·5	159·0	187·0	239·5	239·5	136·5	131·5	273·0	231·0	203·0	195·0
5/2/47	245·0	268·5	271·5	235·0	271·0	223·5	219·5	190·5	339·5	309·0	219·5	234·5
25/2/47	136·0	182·5	137·0	138·0	128·5	156·5	135·0	119·0	208·0	244·5	135·5	147·0
10/4/47	260·5	169·5	178·5	238·0	161·0	170·5	165·5	160·5	202·0	206·5	149·0	153·0
8/5/47	297·5	281·5	290·0	333·5	284·0	325·5	213·5	124·0	285·5	422·5	321·5	335·0
Average	189·4	195·8	180·8	193·1	191·1	201·6	161·0	130·8	251·9	268·7	182·0	188·7
Per cent of available time	16·0	16·5	15·3	16·3	16·1	17·0	13·6	11·0	21·3	22·7	15·4	15·9
29/6/47	298·5	385·5	322·0	248·5	434·5	396·0	220·0	234·5	230·5	231·5	275·5	244·5

TABLE XV. TIME SPENT LYING DOWN (MIN).

Date.	T1	T2	T11	T12	T13	T14	T17	T18	T23	T24	T31	T32
8/11/46	589·0	610·0	592·5	617·5	599·0	545·0	536·5	547·0	683·0	560·5	620·0	587·5
13/12/46	681·0	686·0	555·5	544·0	731·0	653·0	623·0	649·5	647·0	575·0	661·5	640·5
11/1/47	619·0	582·5	558·0	558·0	535·0	540·0	546·0	592·0	525·0	556·5	524·0	567·5
5/2/47	553·5	502·0	501·0	553·5	552·0	608·5	518·0	557·5	549·5	595·0	610·0	613·5
25/2/47	683·0	618·0	639·5	599·0	693·0	691·5	621·5	610·0	664·5	626·0	693·0	720·0
10/4/47	567·0	666·0	562·0	536·0	652·0	637·0	555·5	590·0	664·5	687·0	670·5	641·0
8/5/47	454·5	470·0	398·5	376·5	485·0	407·0	395·0	522·0	436·0	416·5	444·0	440·0
Average	592·4	590·6	543·9	540·6	606·7	583·2	542·2	581·1	595·6	573·8	603·3	601·4
Per cent of available time	50·0	49·8	45·9	45·6	51·2	49·2	45·8	49·0	50·3	48·4	50·9	50·8
29/6/47	762·0	642·5	690·5	741·0	583·5	593·0	733·5	755·0	867·0	879·5	687·0	749·5

(2) The differences between sets of twins are in many cases very great, the range being 138 min. for grazing time, 114 min. for loafing time, and 60 min. for lying down.

Table XVI. Average Grazing Times for Individual Cows

Cow No.	Producing Ability.	Av. Time. Min.	Means for Sets.	Deviation from Mean.	
				Actual.	Per cent.
T1	Good	403·1	400·9	2·2	0·55
T2		398·6			
T11	Medium	460·4	455·8	4·6	1·01
T12		451·2			
T13	Medium	387·2	393·7	6·5	1·65
T14		400·2			
T17	Good	481·8	477·5	4·3	0·90
T18		473·1			
T23	Poor	337·5	340·0	2·5	0·74
T24		342·5			
T31	Poor	399·7	397·3	2·4	0·60
T32		394·9			
Average		410·9	410·9	3·75	0·91

Table XVII. Average Loafing Time for Individual Cows

Cow No.	Av. Time. Min.	Mean for Sets.	Deviation from Mean.	
			Actual.	Per cent.
T1	189·4			
T2	195·8	192·6	3·2	1·66
T11	180·8			
T12	193·1	186·9	6·2	3·32
T13	191·1			
T14	201·6	196·3	5·2	2·65
T17	161·0			
T18	130·8	145·9	15·1	10·35
T23	251·9			
T24	268·7	260·3	8·4	3·23
T31	182·0			
T32	188·7	185·3	3·4	1·83
Average	194·6	194·6	6·9	3·55

The grazing-behaviour pattern of a dairy cow on pasture depends thus in a high degree on her individuality. The knowledge of this fact is most important, partly from the point of view of grazing trial technique and partly because of the implication it throws on the question of food consumption under free intake conditions. Analysis of variance for the time spent in the three activities is presented in Table XIX.

TABLE XVIII. AVERAGE LYING TIME FOR INDIVIDUAL COWS

Cow No.	Av. Time. Min.	Mean for Sets.	Deviation from Mean.	
			Actual.	Per cent.
T1	592·4	591·5	0·9	0·15
T2	590·6			
T11	543·9	542·3	1·6	0·30
T12	540·6			
T13	606·7	594·9	11·8	1·98
T14	583·2			
T17	542·2	561·6	19·4	3·45
T18	581·1			
T23	595·6	584·7	10·9	1·86
T24	573·8			
T31	603·3	602·3	1·0	0·17
T32	601·4			
Average	579·6	579·6	7·6	1·31

TABLE XIX. ANALYSIS OF VARIANCE

(A) Time Spent Grazing

Source of Variation.	df.	ss.	ms.	Significance.
Between sets	5	168688	33738	SS
Within sets	6	1393	232	
Between days	6	87109	14518	SS
Days × Sets	30	34794	1160	SS
Residue	36	16014	445	
Total	83	307992		

(B) Time Spent Loafing

Source of Variation.	df.	ss.	ms.	Significance.
Between sets	5	83168	16634	SS
Within sets	6	7798	1300	
Between days	6	307273	51212	SS
Days × Sets	30	52065	1736	SS
Residue	36	27302	758	
Total	83	477606		

(C) Time Spent Lying Down

Source of Variation.	df.	ss.	ms.	Significance.
Between sets	5	36408	7282	S
Within sets	6	9415	1569	
Between days	6	379943	63324	SS
Days × Sets	30	60812	2027	S
Residue	36	60172	1116	
Total	83	526750		

The differences between sets are significant at the one per cent level for grazing and loafing and at the five per cent level for lying down. The differences required for significance are as follows:—

	P > 0.01	P > 0.05
Grazing time	21.4	14.1
Loafing time	50.5	33.3
Lying down time	—	36.9

It will be noted that of the total variances for grazing time, nearly 90 per cent is due to between-set differences while the corresponding figures for loafing and lying times are only 16 per cent and five per cent. From this the following conclusions may be drawn—

(a) In so far as the cow's behaviour pattern on pasture depends on her individuality, this is mainly reflected in the length of time she requires to spend in grazing.

(b) All cows, whether inclined to graze for short or long periods, tend (within fairly narrow limits) to lie down for the same length of time.

(c) As a consequence of (a) and (b) there is a strong tendency for cows which graze only for a short period of the available time to spend a correspondingly longer time in loafing.

(d) The significant days x sets terms for all three activities show that environment-inheritance interactions are of considerable importance in the determination of an animal's behaviour pattern on pasture.

Twin Efficiency Values

The main purpose of this work was to arrive at an estimate of the relative usefulness of monozygotic twins compared with random animals for experimental work on the grazing habits of dairy cattle. Consequently the twin efficiency values were calculated according to the method described in an earlier paper (1), with the following results:—

Grazing time	72
Loafing time	6
Lying time	3

As these values (multiplied by 2) express the number of randomly selected animals one set can replace without loss of statistical efficiency, it seems that monozygotic twins are extremely useful in experimental work on the grazing habits of dairy cattle. This applies especially to the grazing time, which represents the most important activity of a dairy cow.

To yield entirely correct results the twin sets used in uniformity trials should be selected at random. This was, however, not the case in this trial as the twins were on purpose selected to include the two best and two poorest producing sets available.

In a small sample consisting of a total of only six sets, such a procedure is likely to have caused an unduly large between-set variance term, without a corresponding increase of the within-set variances. It is, therefore, probable that the above values somewhat overestimate the efficiency of monozygotic twins.

There are two other objections which must be met before the relative usefulness of monozygotic twins for this purpose can be fully established.

(1) It may be argued that monozygotic twins graze for the same length of time solely because they have very similar food requirements. If this was the case, any two animals which have the same theoretical

food requirements would probably be as efficient as a set of twins for the purpose of grazing trials. A glance at Table XVI, however, shows that there does not seem to be a relationship between the length spent in grazing and the theoretical food requirements in that amongst the cows which grazed for a long period there was one set of good and one set of medium producers. Amongst the cows which grazed for a medium length of time, there was one set each of good, medium, and poor producers.

It is, therefore, suggested that the calculated feed requirements of a cow are a poor guide to her grazing performance, and that cows which are similar in this respect are, as experimental animals in grazing studies, hardly superior to cows chosen at random.

(2) To the casual observer it frequently appears that the habits of monozygotic twins when pastured together are remarkably similar in that they graze simultaneously or stand close together most of the time. If this was the case the similarity in grazing behaviour within sets of twins may be due, at least partly, to mere imitation, which would detract from their value as experimental animals in this respect. It was not possible to graze the twins in different enclosures in order to measure which part of the concordance in grazing habits was due to imitation and which part to innate physiological compulsion. However, the following analysis shows that imitation cannot have been a very important factor in causing the similarities in twins. It has been calculated from the data collected on one day chosen at random (13 December 1946) that two members of the same set of twins on an average grazed simultaneously only for 80.0 per cent of the total time spent in this activity, whereas for non-twins, paired to bring together animals with as nearly as possible similar grazing times, the corresponding figure was as high as 71.1 per cent. It can, therefore, be concluded that in so far as imitation is a factor influencing the grazing pattern of monozygotic twins, it may also influence a whole herd of cows. This point is illustrated in Fig. 5 which represents the behaviour pattern for all 12 cows on four different days. There is a specific similarity in the pattern within sets of twins on the same day which is quite noticeable. On the other hand, there is also an obvious or general similarity in the behaviour pattern of all cows on the same day when compared with any of the other three days.

Walking

The average distances walked by the cows on the various trial days are shown in Table XX.

TABLE XX. AVERAGE DISTANCES WALKED
(Mean Values for 12 Cows)

Date.	Average Distance. (Yd.)
8/11/46	3,053·9
13/12/46	2,535·1
11/1/47	3,199·9
5/2/47	3,471·3
25/2/47	2,815·3
10/4/47	3,360·7
8/5/47	2,830·0
Average	3,038·0
29/6/47	1,868·8

FIG. 5.—Behaviour pattern for individual cows on four different days.

The mean distance was 3,038 yards, or approximately one and three-quarter miles. Although this seems short it gives a cow the opportunity to cover a great part of a one acre paddock, such as was used in these trials. To show this, Fig. 6 has been prepared where the track of T11 on 8 November 1946 has been plotted.

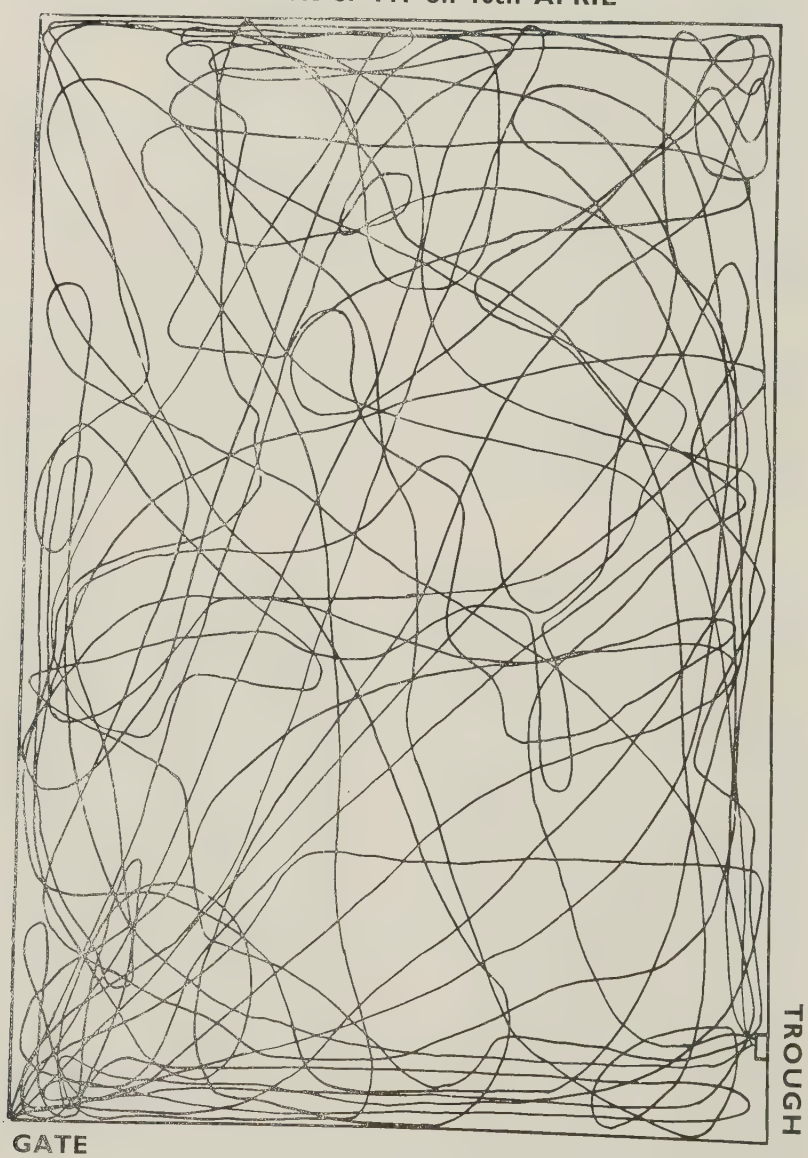

FIG. 6.—Track of T11 on 10 April 1948 (see text).

It will be seen from Table XXI that the differences between days are significant on the one per cent level and differences of 207 and 154 yards are required at the one per cent and five per cent levels respectively.

Table XXI. Analysis of Variance : Distance Walked (yards)

Source of variation.	df.	ms.	Significance.
Between sets	5	616825	S
Within sets	6	93160	
Between days	6	1328226	SS
Days × sets	30	198905	SS
Residue	36	34522	
Total	83		

An interpretation of the results is rather difficult as the factors which may influence walking, by their very number and diversity, tend to obscure the issue. Under such circumstances, it is most convenient to view, in the light of a general discussion based on observation from these trials, the findings on the main reasons why cows walk while on pasture.

Search for Feed

It was noticeable that the cows seldom stopped more than a few moments on the same spot but moved continuously, apparently searching for more palatable grass and frequently grazing as they walked along. Grass of poor palatability may thus conceivably increase the distance walked.

Search for Water

When a cow felt the urge to drink she would suddenly stop grazing and walk straight to the water-trough, rarely pausing to graze on the way. As all paddocks were of the same size, day-to-day differences cannot be accounted for by variation in the distance to the trough. Later, it will be shown that the frequency of drinking varied considerably from day to day and this must certainly have been a factor influencing walking.

Weather

Sudden cold, rain showers with blustering winds caused the cows to turn their backs against the wind and walk from wherever they happened to be to the fence furthest from the wind direction where they huddled together until the shower passed. This probably was the cause of the relatively long distances walked on 8 November 1946. Hot weather, such as on 5 February 1947, seemed to make the cows uncomfortable to such an extent as to cause aimless walking. It must, however, be remembered that in this experiment no shade was provided; if such had been available it is possible that the cows would have stopped for long periods in the shade, thus spending less time in walking.

Flies

On one day at least, 11 January 1947, the flies seemed to cause the cows to walk more than otherwise would have been necessary, in an attempt to avoid the irritation.

Gregariousness

When grazing, the crows were generally spread quite evenly over the paddock. However, they tended to congregate in lying down. It was especially noticeable during the night, when often only a few cows were grazing simultaneously, that when a cow had finished grazing she immediately returned to the area where the other cows were lying. This action was sometimes initiated by a short leap accompanied by a low

bellow. The twins provided a special case of gregariousness in that the members of a set of twins after having strayed some distance from each other while grazing sought each other's company at frequent intervals.

Individuality

Table XXII shows the average distance each animal walked.

TABLE XXII. AVERAGE DISTANCES WALKED BY INDIVIDUAL COWS (YARDS)

Cow No.	Av. Distance. Yd.	Mean for Set.	Deviation from Mean.	
			Actual.	Per cent.
T1	3040·7	3166·2	125·5	3·96
T2	3291·7			
T11	3283·7	3241·4	42·3	1·30
T12	3199·0			
T13	2760·4	2843·3	82·8	2·91
T14	2926·1			
T17	3039·9	3063·3	23·3	0·76
T18	3086·6			
T23	2621·1	2721·6	100·5	3·69
T24	2822·1			
T31	3262·3	3192·5	69·8	2·19
T32	3122·7			
Average	3038·0	3038·0	74·5	2·45

Results from analysis of variance are shown in Table XXI and the distances walked by each cow on each trial day are given in Table XXIII. It will be seen that the differences between sets are smaller than those obtained between days, but they are nevertheless significant at the one per cent level. The differences required for significances were 135 and 89 yards at the one per cent and five per cent levels respectively. Thus the sets T13 - T14 and T23 - T24 covered significantly shorter distances than the other sets. T23 - T24 grazed for a much shorter time than the other animals and it is likely that they, for this reason, did not need to walk as far. The relatively short distances walked by T13 - T14 were associated with their lethargic temperaments.

The days x sets-term is highly significant, indicating that also for this activity environment-inheritance interaction is of importance.

Twin Efficiency Value

Monozygotic twins are only little more efficient than randomly selected animals for work on the walking activity as evidenced by the fairly low twin-efficiency value of 3.

The tendency of monozygotic twins to stay together when pastured, so often remarked upon by casual observers, was investigated using the following method.

From the records of the trial on 8 November 1946, ten instances at which all cows were grazing simultaneously were chosen at random and the mean distances between the members of each set of twins were compared with the mean distances between them and all other cows.

Table XXIII. Distances Covered (yards)

Date.	T1	T2	T11	T12	T13	T14	T17	T18	T23	T24	T31	T32
8/11/46	3542	3496	2452	2560	2845	3050	3795	3800	1877	2615	3275	3340
13/12/46	2344	2615	2807	2515	1971	2484	2396	2577	2200	2644	2988	2880
11/1/47	3262	3422	3432	3539	3107	3083	2773	2897	2974	2975	3454	3481
5/2/47	3525	3680	3700	3575	3655	3470	3645	3515	3270	3040	3480	3100
25/2/47	2728	3369	2820	3025	2739	2645	2591	2910	2385	2733	3209	2630
10/4/47	3036	3257	4270	4048	2742	3075	3377	3286	2773	2992	2559	3914
8/5/47	2848	3203	3505	3131	2264	2676	2702	2621	2869	2756	2871	2514
Average	3040·7	3291·7	3283·7	3199·0	2760·4	2926·1	3039·9	3086·6	2621·1	2822·1	3262·3	3122·7
29/6/47	1983	2207	1361	1596	1601	2111	1986	1645	1669	1884	2229	2154

These calculated mean values were 20.3 yd. and 31.88 yd. respectively, indicating that on an average the distance from one member of a set of twins to her co-twin was ·63 per cent of the mean distances from all other cows grazing in the paddock.

There is quite a wide variation between sets of twins in this respect as Table XXIV shows.

TABLE XXIV. TENDENCY OF TWINS TO STAY TOGETHER

	T31-T32.	T13-T14.	T23-T24.	T17-T18.	T11-T12.	T1-T2.	Mean.
Mean distances in yd. between members.	14·0	18·3	19·6	16·0	22·2	34·7	20·3
Mean distances in yd. between members and all other cows.	29·3	29·8	36·3	29·0	34·7	32·2	31·9
Ratio.	·48	·52	·54	·55	·64	1·07	·64

Defecations, Urinations, and Drinks

All occasions of defecations, urinations, and drinks, were recorded. No attempt was made to measure the actual amounts of fæces or urine voided, or the amount of water consumed. In the following, it will be assumed as a working hypothesis that the respective quantities resulting from these functions were roughly proportionate to the number of times they occurred.

Defecations

The number and average number of defecations on the various days are shown in Tables XXV and XXVI respectively.

TABLE XXVI. AVERAGE NUMBER OF DEFECATIONS
(Mean Values for 12 Cows)

Date.	7 a.m.-3 p.m.		5 p.m.-4.45 a.m.		Yard.		Total.
	No.	Per cent.	No.	Per cent.	No.	Per cent.	
8/11/46	4·6	57	3·0	37	0·4	6	8·0
13/12/46	5·5	50	5·2	47	0·4	3	11·1
11/1/47	6·9	48	6·9	48	0·6	4	14·4
5/2/47	7·5	55	5·9	43	0·2	2	13·6
25/2/47	6·9	49	6·8	49	0·2	2	13·9
10/4/47	7·8	60	5·1	40	—	—	12·9
8/5/47	6·1	53	5·3	45	0·1	2	11·5
Average	6·45	53	5·44	45	·31	2	12·2
29/6/47							8·9

The differences between days were significant at the one per cent level, a difference of 2.0 times being required for statistical significance on this level, and 1.5 on the five per cent level.

There seemed to be a definite, although not very strong, relationship between the maximum air temperatures and the number of times the cow defecated (see Fig. 7). It is difficult to decide whether this was entirely an epiphenomenon due to increasing fibre content of the grass or whether it was at least partly a direct temperature effect. There is

Table XXV. Number of Defecations

Date.	T1	T2	T11	T12	T13	T14	T17	T18	T23	T24	T31	T32
8/11/46	10	10	7	10	7	7	7	7	6	7	8	10
13/12/46	11	15	18	15	11	8	8	9	9	7	13	9
11/1/47	18	19	16	17	11	11	14	11	11	11	21	13
5/2/47	15	15	19	19	14	12	13	11	12	9	13	12
25/2/47	16	15	17	19	13	9	11	11	15	12	13	15
10/4/47	12	14	13	16	13	14	10	9	11	13	14	15
8/5/47	16	14	13	11	12	10	12	11	8	8	14	9
Average	14·0	14·6	14·7	15·3	11·6	10·1	10·7	9·9	10·3	9·6	13·7	11·9
29/6/47	8	12	10	13	7	7	10	5	6	7	15	7

Table XXVII. Number of Urinations

Date.	T1	T2	T11	T12	T13	T14	T17	T18	T23	T24	T31	T32
8/11/46	5	14	5	7	9	7	10	6	3	5	8	9
13/12/46	8	10	10	8	7	6	12	14	9	6	9	8
11/1/47	9	11	10	10	14	9	14	14	5	5	10	4
5/2/47	11	11	11	10	8	10	12	15	10	10	13	10
25/2/47	6	8	8	9	10	9	11	7	12	5	10	7
10/4/47	9	12	12	14	11	10	17	13	9	6	16	13
8/5/47	14	14	12	14	20	13	21	18	9	7	17	6
Average	8·9	11·4	9·7	10·3	11·3	9·1	13·9	12·4	8·1	6·3	11·9	8·1
29/6/47	12	10	12	9	7	6	10	9	6	9	11	9

some indirect evidence that high temperature *per se* may increase the number of defecations per time unit in that cattle, through this function, not only eliminate metabolic waste products, but also surplus heat by increasing water content of the fæces, thus presumably increasing the volume of fæces and the number of defecations.

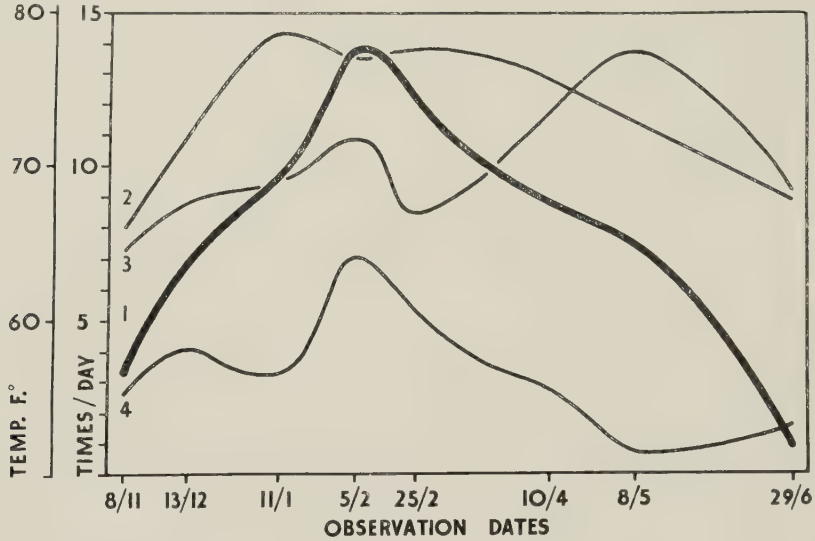

FIG. 7.—Relationship between maximum daily air temperatures [thick line (1)] and daily average numbers of defecations (2), urinations (3), and drinks (4).

Urinations and Drinks

These functions will be discussed together as they are at least partly physiologically interdependent. However, it is not to be expected that there should be a direct relationship between drinking and loss of water through urination as these functions are only a part of the outward manifestations of the metabolic, catabolic and thermoregulatory processes which maintain the water balance of the animal. The very complicity of these processes makes an interpretation of the results rather difficult. The number of urinations on the various days is shown in Table XXVII, and the average number for the same days is presented in Table XXVIII.

TABLE XXVIII. AVERAGE NUMBER OF URINATIONS
(Mean Values for 12 Cows)

Date.	7 a.m.-3 p.m.		5 p.m.-4.45 a.m.		Yard.		Total.
	No.	Per cent.	No.	Per cent.	No.	Per cent.	
8/11/46	3·5	48	3·3	45	0·5	7	7·3
13/12/46	4·6	51	3·6	41	0·7	8	8·9
11/1/47	5·0	53	4·2	43	0·4	4	9·6
5/2/47	4·5	41	6·4	59	—	—	10·9
25/2/47	3·7	43	4·5	53	0·3	4	8·5
10/4/47	7·5	63	4·1	35	0·2	2	11·8
8/5/47	7·9	58	5·7	41	0·1	1	13·7
Average	5·24	52	4·55	45	0·33	3	10·12
29/6/47							9·1

The differences between days were significant at the one per cent level, the differences required for statistical significance being 2.3 at the one per cent level and 1.8 at the five per cent level.

The average frequency of urinations increased (except for a drop on 25 February 1947) until 8 May 1947. This tendency was probably due to increasing air temperatures (Fig. 7) and the presumably higher dry matter content of the grass which caused the cows to consume more water (see below). However, this tendency continued on 10 April and 8 May 1947 despite lower temperatures, but on these days the high frequency of urination was probably due to a high involuntary intake of water due to increasing water content and surface moisture of the ingested grass. In addition, it is likely that the lower air temperatures at this period inhibited the loss of water through the lungs and the skin to such an extent that the task of elimination of surplus water had to be accomplished mainly by the renal system.

The number and average number of drinks on the various days are shown in Tables XXIX and XXX.

Table XXIX. Number of Drinks

Date.	T1	T2	T11	T12	T13	T14	T17	T18	T23	T24	T31	T32
8/11/46	2	2	3	5	2	2	2	4	5	1	2	1
13/12/46	3	4	6	6	3	2	4	5	5	4	3	4
11/1/47	3	2	4	4	5	3	3	7	3	2	1	3
5/2/47	5	7	12	11	7	7	8	5	8	8	4	2
25/2/47	5	8	7	7	4	5	6	6	4	4	3	3
10/4/47	2	1	3	5	2	4	4	3	3	1	3	2
8/5/47	—	—	1	—	—	—	1	1	1	1	2	1
Average	2·8	3·4	5·1	5·4	3·3	3·3	4·0	4·4	4·1	3·0	2·6	2·3
29/6/47	1	—	1	2	1	2	3	1	2	3	2	1

Table XXX. Average Number of Drinks
(Mean Values for 12 Cows)

Date.	7 a.m.-3 p.m.		5 p.m.-4.45 a.m.		Yard.		Total.
	No.	Per cent.	No.	Per cent.	No.	Per cent.	
8/11/46	1·5	58	1·1	42	—	—	2·6
13/12/46	2·9	69	1·2	31	—	—	4·1
11/1/47	1·7	52	1·6	48	—	—	3·3
5/2/47	5·5	79	1·5	21	—	—	7·0
25/2/47	3·5	68	1·7	32	—	—	5·2
10/4/47	1·7	61	1·0	36	0·1	3	2·8
8/5/47	0·7	100	—	—	—	—	0·7
Average	2·49	68	1·15	32	0·1	—	3·65
29/6/47							1·6

The differences between days were significant at the one per cent level, the difference required for statistical significance being 1.2 on the one per cent level and 0.9 on the five per cent level.

As Fig. 7 shows there was a general tendency for the number of drinks to increase as the maximum air temperatures increased. This, however, was due probably not only to greater requirement of water for thermoregulatory purposes, but also to the increasing demand of

water which the higher dry matter content of the grass at this time imposed on the digestive process. Conversely, the very low number of drinks on 8 May 1947 was due not only to low air temperatures on that day but also to the fact that the grass was very lush and, in addition, laden with surface moisture as a consequence of frequent showers.

Individuality

Table XXXI shows the daily average number of defecations, urinations and drinks respectively obtained for each animal.

The differences between sets are highly significant for defecations and drinks but not significant for urinations. Differences required at the one per cent and five per cent levels are 2.9 and 1.9 for number of defecations and 1.5 and 0.9 for drinks. The twin efficiency values have been calculated as follows:—

Number of defecations	8
Number of urinations	1
Number of drinks	5

It is clear that for experimental work involving defecations and drinks monozygotic twins are very useful material, but for that involving urinations they show no advantage over randomly selected animals.

The analysis of variance is presented in Table XXXII.

TABLE XXXII. ANALYSIS OF VARIANCE

A. Number of defecations

Source of Variation.	df.	ss.	ms.	Significance.
Between sets	5	324	68·8	SS
Within sets	6	26	4·3	
Between days	6	354	59·0	SS
Days × Sets	30	136	4·5	NS
Residue	36	121	3·4	
Total	83	961		

B. Number of urinations

Source of Variation.	df.	ss.	ms.	Significance.
Between sets	5	247	49·3	NS
Within sets	6	108	18·0	
Between days	6	346	57·8	SS
Days × Sets	30	216	7·2	S
Residue	36	160	4·5	
Total	83	1,077		

C. Number of drinks

Source of Variation.	df.	ss.	ms.	Significance.
Between sets	5	68	13·7	SS
Within sets	6	7	1·2	
Between days	6	296	49·3	SS
Days × Sets	30	82	2·7	S
Residue	36	44	1·2	
Total	83	497		

Table XXXI. Average per Cow Frequence of Defecations, Urinations and Drinks

	T17	T18	T23	T24	T31	T32
Defecation	10·7	9·9	10·3	9·6	13·7	11·9
Urination	13·9	12·4	8·1	6·3	11·9	8·1
Drinks	4·0	4·4	4·1	3·0	2·6	2·3

	T1	T2	T11	T12	T13	T14
Defecation	14·0	14·6	14·7	15·3	11·6	10·1
Urination	8·9	11·4	9·7	10·3	11·3	9·1
Drinks	2·8	3·4	5·1	5·4	3·3	3·3

The fact that the interactions days x sets are significant in the case of urinations and drinks indicates that inherited factors cause individual fluctuations in respect to these activities as a response to the impact of specific environmental conditions.

Distribution

It has been previously pointed out that many farmers in New Zealand for the sake of convenience graze their dairy cows during the period between the afternoon and morning milking on an area which probably is smaller than that required for maximum feed intake. It has been argued by grassland experts that this practice may also be detrimental from the point of view of having the effect of transferring fertility in the form of dung and urine from the day paddocks to the night paddocks, thus slowly depleting the plant nutriment stores of the former. The data obtained in these trials were, therefore, analysed in order to discover the number of times animals defecated and urinated in the two periods concerned. The results (see Tables XXVI and XXVIII) show that the ratio of defecations and urinations during the two periods was on an average not greatly different from the ratio of the average time spent in grazing during the same periods. The following tentative conclusion can, therefore, be drawn: provided that the area of the night paddock is approximately two-thirds of the day paddock, the transfer of fertility is likely to be negligible. This, however, is a condition seldom met with in practical farming.

Of late years, there has been a great deal of propaganda in the popular agricultural press of New Zealand on the advantages of collecting and distributing dung and urine voided in the milking yards. Such work, if carried out entails expensive tanks, equipment and labour. Results from these trials show (Tables XXVI and XXVIII) that of the total number of defecations and urinations, only two per cent and three per cent respectively occurred in the yards. These findings indicate the necessity for additional factual information on this question before the expenditure of money on equipment and installations can be advocated with confidence.

Speed of Grazing and Rumination

In order to gain some information on the speed of grazing and rumination habits of dairy cows, two sets of twins (T1 - T2 and T17 - T18) were observed for a 24-hour period during which every

bite of grass, each bolus and each movement of the jaw when ruminating were recorded in minute intervals for each cow. This procedure was decided upon in view of the lack of previous information as to the magnitude of sampling errors involved. Owing to the lack of labour, only three animals could be observed simultaneously. T1 - T2 and T18 were thus observed on 12 May 1947 and T17 on 8 May 1947 in conjunction with the grazing trial carried out on that day.

Rate of Grazing

Table XXXIII shows the result for grazing.

The average number of bites per day (23,966) was surprisingly high. Assuming an intake of 70 kg. grass per day, a figure that lines up with recorded observations at Ruakura, a cow grazing at this rate obtained only approximately 3 g. of grass per bite. It is, therefore, evident that a cow can be, if she so wishes, a very selective grazer in that she not only can select a specific area for grazing but can also select the particular pasture plants she prefers amongst the vegetation on this area. Observations support this suggestion.

TABLE XXXIII. RATE OF GRAZING

	T1	T2	T17	T18	Average.
Grazing time (min.)	354	404	576·5	534·5	467·3
Total No. of bites	17,025	20,538	30,955	27,346	23,966·0
No. of bites between 7 a.m.-3 p.m.	10,424	12,289	18,503	17,443	14,664·8
No. of bites between 5 p.m.-4.45 a.m.	6,601	8,249	12,452	9,903	9,301·3
Av. rate of grazing (bites/min.)	48·1	50·8	53·7	51·2	51·3
Rate of grazing between 7 a.m.-3 p.m.	48·3	50·9	56·2	52·0	52·2
Rate of grazing between 5 p.m.-4.45 a.m.	47·8	50·8	50·4	50·0	49·9

There was a pronounced difference between the two sets of twins in total bites per day, but this was almost entirely due to the differences in times spent grazing, as the average rate of grazing per minute was very similar for all four cows.

There was hardly any difference in the average speed of grazing during the periods 7 a.m. to 3 p.m. and 5 p.m. to 4.45 a.m. The speed of grazing was, however, not constant throughout the 24 hours. In fact the number of bites per minute varied quite considerably, as is illustrated by Fig. 8.

It will be noted that the rate was highest in the beginning of a grazing cycle. This phenomenon was most pronounced in the cycles immediately following milking.

Rumination

The rumination process may be divided into four phases:—

(1) Regurgitation of a certain amount of partly digested food (bolus);

(2) Mastication;

(3) Swallowing;

(4) A period of seeming inactivity generally lasting only a few seconds, after which the process is repeated.

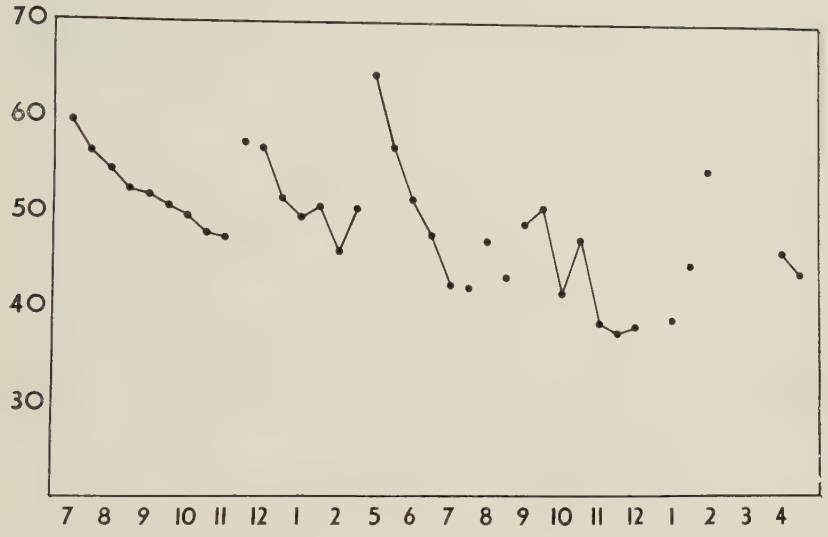

Fig. 8.—Changes in frequency of bites per minute throughout a 24-hour period. Average of two sets of twins.

No attempt was made to measure the time required in the various phases; consequently it was possible to calculate the rate of mastication only on the total rumination time and not, as had been ideal, on the actual time spent in mastication.

Because the computed average values are based on the behaviour of only four individuals on only one day, it is not possible to draw general conclusions. Consequently, emphasis in presenting the results will be laid on the differences and similarities within and between the two sets of twins.

Table XXXIV shows that T1 - T2 ruminated for a longer total time than T17 - T18 and for a greater number of periods. However, the average length of each period was shorter for the former than for the latter. The members of the same set of twins did not show any similarities as to the total number of bites.

The within-set differences were due in the case of T1 - T2 to the fact that T1 took fewer bites to each bolus than did T2, and in the case of T17 - T18, to the fact that T18 ruminated for a shorter time than T17.

Table XXXV shows that T17 - T18 took many more bites to each bolus than T1 - T2. It also indicates that generally the number of bites per bolus was higher during the night than during the day.

T1 - T2 chewed more boluses per time unit than T17 - T18. There was no difference between day and night in this characteristic. (See Table XXXVI.)

The difference between the two sets becomes still more apparent when their rumination habits are considered in relation to the grazing. It is quite evident from Table XXXVII that T1 - T2 masticated their ingested food much more thoroughly than T17 - T18.

TABLE XXXIV. RUMINATION

	T1	T2	T17	T18	Average.
Duration (min.)	341	347	327	282	324·3
Number of boluses	432	414	320	267	358·3
Number of bites	15,525	18,657	18,686	15,600	17,117
Number of periods	17	15	11	10	13·3
Average duration of each period (min.)	20·1	23·1	29·7	28·2	24·5

TABLE XXXV. BITES PER BOLUS

Time Period.	T1	T2	T17	T18	Average.
7 a.m.-5 p.m.	34·3	43·2	51·7	54·2	42·7
5 p.m.-7 a.m.	36·6	50·0	60·3	59·1	49·5
Average	35·9	45·1	58·4	58·4	47·8

TABLE XXXVI. BOLUSES PER MINUTE OF RUMINATION TIME

Time Period.	T1	T2	T17	T18	Average.
7 a.m.-5 p.m.	1·26	1·22	·97	1·09	1·17
5 p.m.-7 a.m.	1·27	1·18	·98	·93	1·09
Average	1·27	1·19	·98	·95	1·10

TABLE XXXVII. RELATIONSHIP BETWEEN RUMINATION AND GRAZING

	T1	T2	T17	T18	Average.
Rumination/grazing (min)	1·00	0·86	0·57	0·53	0·75
Rumination/grazing (bites)	0·91	0·91	0·60	0·57	0·71
No. boluses/grazing (min)	1·22	1·02	0·56	0·50	0·77

The fact that pronounced differences do exist between animals naturally constitutes a strong challenge to an enquiry into the underlying causes of such variations in the manifestations of a physiological process and ultimately into their effects on other processes such as digestion, growth and milk production. At present there are no indications as to the solution of these problems. Both sets are better than average producers, but T17 - T18 are decidedly superior to T1 - T2.

Judging from the grazing figures, the former cows probably consume much more feed than the latter. T1 - T2 are frequently prone to digestive upsets (other than bloat), with consequent loss of production. This is contrary to expectation as has been shown, they graze less and ruminate longer than T17 - T18.

It is hoped that the queries which have been raised will be elucidated by using these animals in further work involving measurement of individual feed intake and their capacity to digest the consumed feed.

The distribution of rumination throughout the 24-hour period is shown diagrammatically in Fig. 9.

Table XXXVIII contains a summary of the activities of the four cows which shows that on an average the animals spent only a little over four hours in complete rest. Whether the cows slept the whole or part of this time is a question which was not investigated, but casual observations indicated that they were inactive with eyes closed for only a few minutes at a time.

Table XXXVIII. Distribution of Rumination

Occupation.		T1	T2	T17	T18	Average.
Loafing	ruminating	101·0	121·0	30·0	10·0	65·5
	not ruminating	266·5	209·5	183·5	206·5	216·5
Lying	ruminating	170·0	174·0	199·0	187·0	182·5
	not ruminating	293·5	276·5	196·0	247·0	253·3
Milking	ruminating	70·0	52·0	98·0	85·0	76·3
	not ruminating	185·0	203·0	157·0	170·0	178·8

In this connection, it is of interest to point out that the necessity to ruminate is not, in some cases at least, the factor which causes the cyclic pattern of grazing.

This is evidenced for instance by the behaviour of T18 on 12 May 1947. Between 7 a.m. and 7.30 p.m. she grazed for over seven hours while during the same time she ruminated on two occasions only for 12 and 20 min. respectively. The second of these periods occurred actually during the afternoon milking. In spite of the short time spent in ruminating, the typical four cycle grazing pattern was quite apparent as can be seen in Fig. 9.

Discussion

The management of dairy cattle on wholly pastoral conditions such as in New Zealand presents the farmer with a host of problems not encountered in most other countries where the cows are fed according to feed norms for the greatest part of the year. The most obvious drawback with a free-intake system of feeding is that in practice all cows in a herd, whether good, medium or poor producers, are provided with the same potential level of nutrition. How such conditions influence the feed-intake of individual cows with different nutritional requirements is a question of prime importance from production, health and breeding points of view.

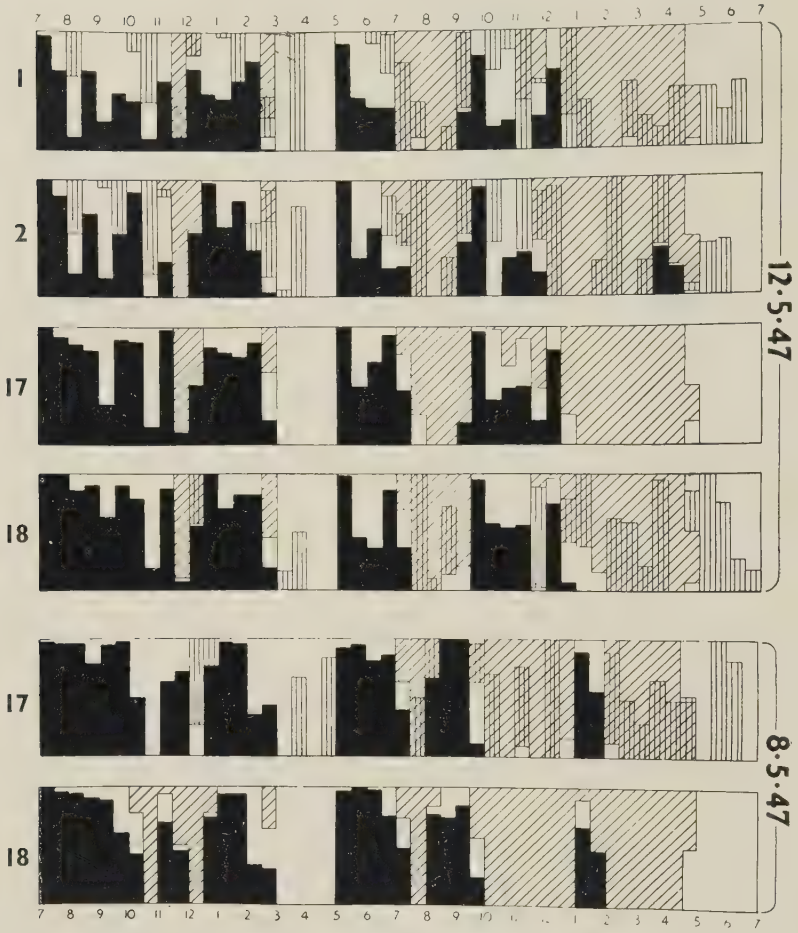

FIG. 9.—Diagram showing the distribution of grazing, loafing, lying and rumination for two sets of twins. Periods of rumination are represented by the areas marked by longitudinal lines, the other activities are marked as in Figs. 4 and 5. T1, T2 and T18 were observed on 12 May 1947 and T17 on 8 May 1947. For completeness' sake, the behaviour patterns of T17 and T18 are shown also on the days on which their rumination was not observed.

By employing the technique described in this paper, it has been possible to measure accurately the extent to which the behaviour pattern of dairy cows on pasture varies according to the inherited make-up of each cow and as a result of the impact of specific environmental conditions.

The interpretation of the differences between cows and between days which have been demonstrated to occur is, in many instances, not obvious. This is partly due to the fact that differences in the physiological processes which cause cow-to-cow variations are not fully understood, and partly because the environmental factors involved are almost inevitably so many and diverse so as to make the day-to-day differences inexplicable in terms of a single variable.

These difficulties have been emphasized by the lack of a simple reliable method of measuring the individual feed-intake of dairy cows; neither is there available a wholly satisfactory method for the measurement of group intake. For a complete understanding of the grazing habits of dairy cows it is necessary, in addition, to have an accurate knowledge of the capacity of the individual cows to utilize pasture, and of the digestibility of grass consumed at different time periods. Present methods of obtaining the required data are very inadequate.

It is hoped that the intensive work at present carried out at Ruakura Animal Research Station will provide a solution to these technical difficulties in the near future. Only then will it be possible to evaluate more completely the significance of the variations which do occur in the grazing habits of dairy cows.

Acknowledgments

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BOOK REVIEW

PRINCIPLES OF ANIMAL ECOLOGY

By W. C. ALLEE, A. E. EMERSON, ORLANDO PARK, THOMAS PARK, and KARL P. SCHMIDT. W. B. Saunders Company, Philadelphia and London, 1949. Pp. xii + 837; figs. 263. Price $14.

The wide scope of this book is indicated not merely by the titles of its 35 chapters, but rather by the range of the selected bibliography of over 2,500 items, many of which have several page citations. It is a monumental work—a *vade-mecum*—in which the authors, prominent in their individual fields, have succeeded in bringing together their own experiences and the essential features of the subject found in the vast literature that now exists.

Though each author prepared the first draft of the parts in which he is specially interested, the whole has been collated with the object of submerging the individual in favour of the authors as a community—a truly ecological approach; nevertheless, as in all communities, the dominance of one or another of the individuals cannot be altogether suppressed here and there; while quite apart from the scientific side of the book, one senses the liberal approach of the authors toward others which lends a pleasing personal atmosphere to the work.

The authors' efforts have been "directed primarily towards the presentation and documentation of general ecological principles"; and, though the title of the book is Animal Ecology, the close link with plant ecology is naturally considered as clearly indicated by the fact that the authors "fully recognise the need for a future work on the Principles of Ecology which will make the logical synthesis of the two fields."

The sections of the book apart from the Introduction (12 pp.) are:—(1) History of Ecology, 60 pp.; (2) Analysis of the Environment, 190 pp.; (3) Population, 173 pp.; (4) The Community, 162 pp.; and (5) Ecology and Evolution, 132 pp.; closing with the Bibliography and Authors' Index, and a well systematized Subject Index.

The historical part traces the various origins of ecology from Grecian times through the ages until the subject had emerged as a recognizable field of science by the close of the 19th century; this is followed by a chronological account of its rapid consolidation and advancement during each decade to 1942 when "ecology, with notable exceptions, was in a healthy and lusty state".

In their "Analysis of the Environment" the authors "discuss ecological principles dealing with the non-living physical environment more or less as a unit"; but on reaching the subject of the ecological relations of the soil they find "a transition to the discussion of biotic aspect of environment and to the consideration of some phases of the biota itself". The Analysis covers meteorological and chemical aspects, water, gases, and combinations of factors.

In the remaining three sections (Population, Community, and Ecology and Evolution) "much of the discussion of the biotic environment is given in direct connection with populations, communities and evolution, rather than in a single part of the book", the aim being to treat these aspects as an interrelated whole, not so much as separate facets in the field of ecology. The discussions on "Population" centre round biological and demographic backgrounds, growth form, population factors and selected problems, and animal aggregations, closing with a chapter on the organization of insect societies. The principles discovered in the study of populations are then applied to the Community—its organization (stratification, metabolism, peridoism), succession and development, to the biome and biome-type in world distribution. In the final section on Evolution, genetics, reproductive isolation and natural selection are ably combined in a discussion toward an interpretation of their relation to ecological evolution.

In a work of this sort one misses a glossary. There are so many of us, not necessarily specialists in ecology, whose work so frequently reaches into that field; to such, the full understanding of ecological principles cannot be attained without accurate definitions of the terminology.

D. M.

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